AD-A054 275 MAGNETIC TECHNOLOGY CANOSA PARK CALIF* F/G 9/1

REPORT OF TEST ON CRYOGENIC COOLER MOTORS.(U)

OCT 77 R D LATHROP, W S OSBORNE, K W KORF DAAK02-75-C-0065

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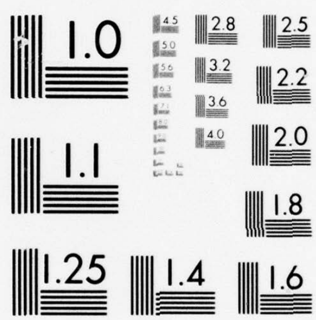

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Magnetic Technology (Div of Vernitron Corp)
21001 Kittridge Street
Canoga Park, CA 91303

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Outer-Rotation-Member Motors
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20. ABSTRACT (*Continue on reverse side if necessary and identify by block number*)

This document provides test data obtained from twelve prototype DC brushless outer rotation motors designed to operate at 20 oz-in and 1100 RPM. Power input, speed-torque, and efficiency curves are provided for ambient temperatures between -54C to 82C and for applied input voltages from 18 to 32 VDC.

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Test Report No. 50285-5
Revision N/C

REPORT OF TEST ON

CRYOGENIC COOLER MOTORS

MANUFACTURED UNDER CONTRACT NO. DD DAA KO2-75-C-0065

by

MAGNETIC TECHNOLOGY
21001 Kittridge
Canoga Park, Calif. 91303

Tested by W. J. O'Brien
Product Manager

Approved by K. W. Kopf 10/6/77
Q.A. Manager

EFFICIENCY AT 20 OZ-IN, 1100RPM

S/N	STALL TORQUE 18,24 & 32 volts	ROOM TEMP.			180^oF			-65^oF		
		18	24	32	18	24	32	18	24	32
285-1	90	.57	.56	.56	.56	.55	.55	.56	.55	.55
285-2	81	.58	.57	.57	.57	.56	.56	.57	.56	.56
285-3	82	.57	.56	.56	.56	.55	.55	.56	.55	.55
285-4	75	.57	.57	.57	.56	.56	.56	.56	.56	.56
285-5	77	.57	.55	.55	.56	.54	.54	.56	.54	.54
285-6	96	.57	.56	.56	.56	.55	.55	.56	.55	.55
285-7	80	.58	.57	.56	.57	.56	.55	.57	.56	.55
285-8	80	.56	.55	.55	.55	.54	.54	.55	.54	.54
285-9	78	.58	.56	.55	.57	.55	.54	.57	.55	.54
285-10	85	.57	.55	.55	.56	.54	.54	.56	.54	.54
285-11	82	.57	.55	.55	.56	.54	.54	.56	.54	.54
285-12	77	.59	.57	.56	.58	.56	.55	.58	.56	.55

REVERSE POLARITY TEST - MOTORS DO NOT RUN - INPUT LOOKS LIKE SHORT CIRCUIT

STALL PROTECTION - ALL MOTORS SHUT OFF WITHIN 4 SECONDS, WHEN STALLED.

TABLE 1 SUMMARY OF TEST RESULTS

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TABLE OF CONTENTS

Description of Test and Test Units

The tests described in this report were run to verify the performance of D.C. brushless motors which were designed to run with high efficiency at 20 oz-in, 1100 rpm.

Each motor consists of a three phase delta wound stator with nine color coded lead wires, a six-pole permanent magnet rotor, a commutation timing plate, a printed circuit board containing LED's and photo-transistors for sensing rotor position and a controller package. It is powered by an 18 to 32 volt input.

The stator leads are brought out from the three corners of the delta winding and from six taps that are connected at positions 1/9 of the winding from each corner. These taps allow the winding drive transistors to be saturated by base current that passes through 7/9 of the winding thus producing torque.

Since in normal configurations the base drive current is lost, this feature allows a higher efficiency.

The controller contains a voltage regulator so that motor speed can be maintained over the full 18 to 32 volt input range. For high efficiency a switching regulator is used. A choke, filter capacitors, catch diode and transitor used in this regulator consume most of the package volume. The rest of the package contains decoding logic to convert the sensor inputs to one of six drive switch states, six power transistor switches with associated drivers, a 5 amp current limiter and a protection circuit that shuts off all the drive transistors if rotation has not started within 4 seconds of power application. This circuit may be resent by removing and reapplying power to the controller. No attempt is made to directly regulate the motor speed. Motor speed is therefore determined by regulator output voltage (which is adjustable through a hole in the controller base), motor back emf and load torque.

Future circuit improvements could include features to directly control motor speed for better speed regulation and higher efficiency.

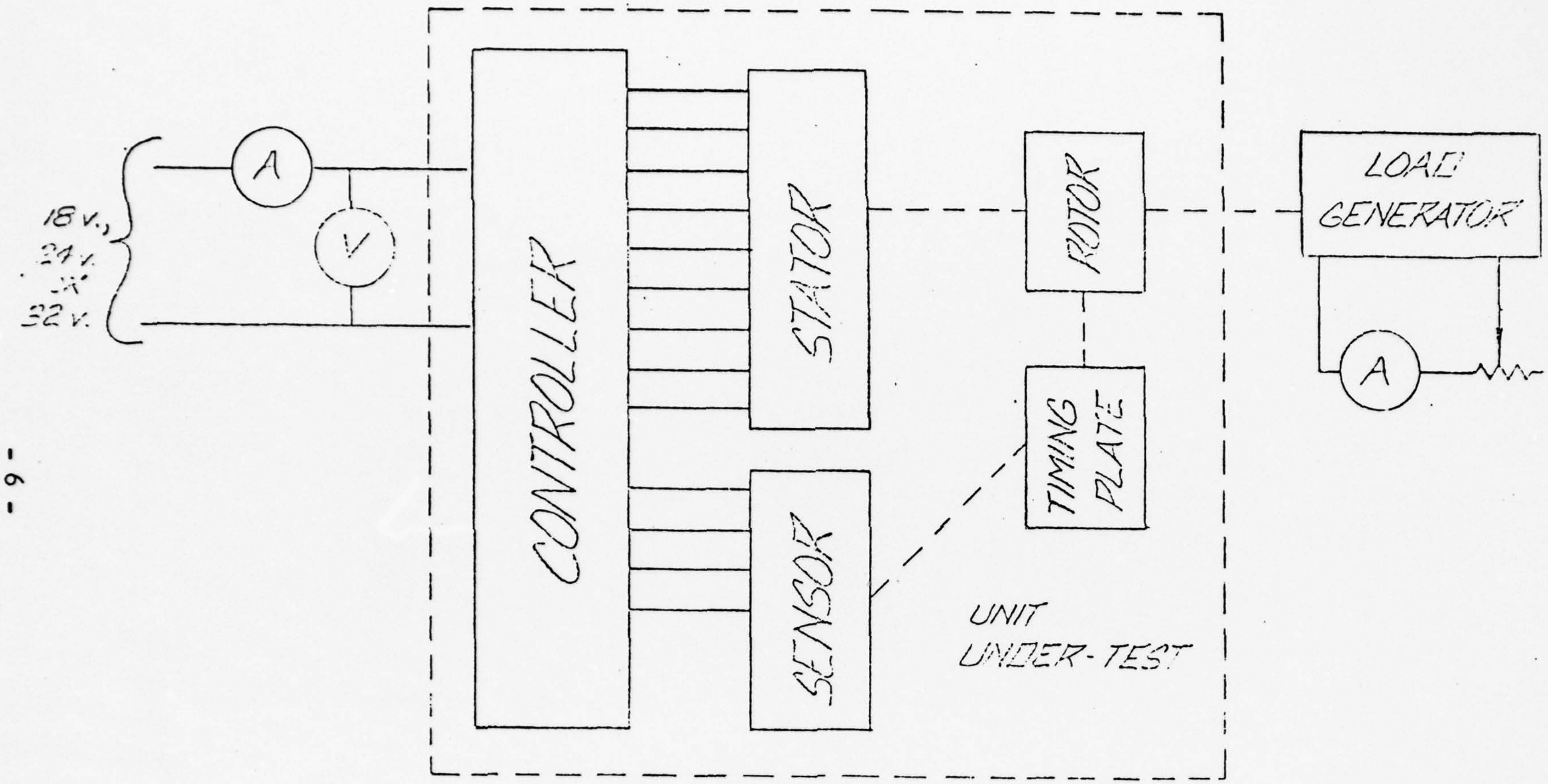


FIGURE #1 - TEST APPARATUS BLOCK DIAGRAM

TEST APPARATUS

Power Supply	NJE QR 60-6
Volt Meter	Weston 911
Ammeter	Weston 911
Ammeter	Weston 81
Load Generator	Magnetic Technology 2813-063
Strobotac	General Radio 1531 A
Temperature Chamber	Delta Design

TEST PROCEDURE

GENERAL

The motor was loaded with the load generator to two different torques. Measurements were taken on the speed, voltages and currents so that the speed-torque and efficiency-torque curves could be calculated and plotted.

The load generator was calibrated so that the torque load could be calculated from the following equation.

$$T = 1.83 + .0022S + 30.6i$$

WHERE:

T = torque in oz-in

S = speed in rpm

i - current in amps

PROCEDURE

1. Apply 24 volts to input.
2. Adjust torque generator to no current flow.
3. Measure motor speed, input voltage, input current.
4. Load torque generator with 33 ohms (approximately 20 Oz-in) and repeat step 3.
5. Raise voltage to 32 volts and repeat 2-4.
6. Lower voltage to 18 volts and repeat 2-4.
7. Place unit in temperature chamber, lower temperature to -65°F and repeat 1-6.
8. Raise temperature to 180°F and repeat 1-6.
9. Calculate the stall torque from the motor torque sensitivity and from the current limit as the motor accelerates from stall.
10. Check stall protection circuit by holding motor at stall. After about 4 seconds, motor should turn off.
11. Check reverse polarity protection.

Conclusions

Because the final configuration of the systems shipped are so much different than the conceptual configuration it is pertinent to provide a chronological history.

The initial configuration called for the electronics to be installed on circuit boards no larger than 2.75 inches in diameter. This electronics configuration was started and proceeded through breadboarding, fabrication and preliminary testing. During final testing it was discovered that the power amplifiers were thermally marginal using the 2N6191 (TO -5 case) power transistors. The combination of higher than anticipated power dissipation, low thermal conductivity of circuit board encapsulant, and the 180°F ambient producted a marginal junction temperature. This resulted in the eventual failure of the transistor(s).

Redesign and re-manufacture of the electronics was immediately began and was completed in two weeks. The reconfiguration moved the power handling transistors to an external board, which reduced the package size length internal to the compressor housing 3/8 of an inch.

Unfortunately, this rework was accomplished without the expressed approval of the COTR, and subsequent discussions resulted in a further modification of the electronics package. This modification moved all the electronics (with the exception of the sensors) external to the compressor package. This reduced the length of the components to be placed in the compressor housing to an overall length of 2.25 inches which was a significant reduction. This modification required that extensive redesign be performed and a contract extention was granted. Rework was accomplished in approximately 90 days and the entire quantity of 12 systems were shipped.

When tests were begun at USAMERDC-NVL, test results obtained at Magnetic Technology could not be duplicated. The systems were subsequently returned to Magnetic Technology for reevaluation and modifications as necessary to duplicate the original test results.

It was determined that reliable operation required extremely critical alignment of the tachometer sensor-led pair.

Therefore, Magnetic Technology offered to eliminate the tachometer circuit and add a voltage regulator to perform the speed control function. This modification was accomplished in approximately 6 weeks and the systems were shipped back to USAMERDC-NVL.

Testing at USAMERDC-NVL was begun, but again test data obtained at Magnetic Technology could not be duplicated. During a visit by Magnetic Technology personnel the week of July 29, 1976, it was determined that the torque generator used by Magnetic Technology was introducing errors that resulted in higher efficiency numbers than were actually being obtained.

Negotiations with USAMERDC-NVL cognizant personnel resulted in the final modification of this contract. Magnetic Technology agreed to repackage the electronics circuitry into a space whose dimensions were 2.75 inches by 3.75 inches by 2 inches. This repackaging required a complete redesign of the circuit boards and some modification of the circuitry. Modification of 6 systems was accomplished in 120 days and the balance of 6 systems was completed on 10-14-77.

Several basic conclusions result from the performance of this contract.

1. The requirement for a voltage regulator in the package penalizes the system in 2 ways. First, it causes the circuitry to increase tremendously in size. Secondly, in an effort to keep the regulator reasonably small, some regulator efficiency is sacrified. If regulated power were supplied to the controller (eliminating the existing regulator) the worst case system efficiency would rise from 52 to 65 percent. The present regulator is 80% efficient and if a larger system regulator were used, regulator efficiencies of greater than 90% would be anticipated.

2. A significant percentage of the motor losses are in the form of iron losses which could be reduced by using a smaller motor. If the stall torque requirements were reduced from 75 oz-in to 40 oz-in, the motor size and attendent iron losses could be substantially reduced and the motor should still be adequate to start a 20 oz-in load.

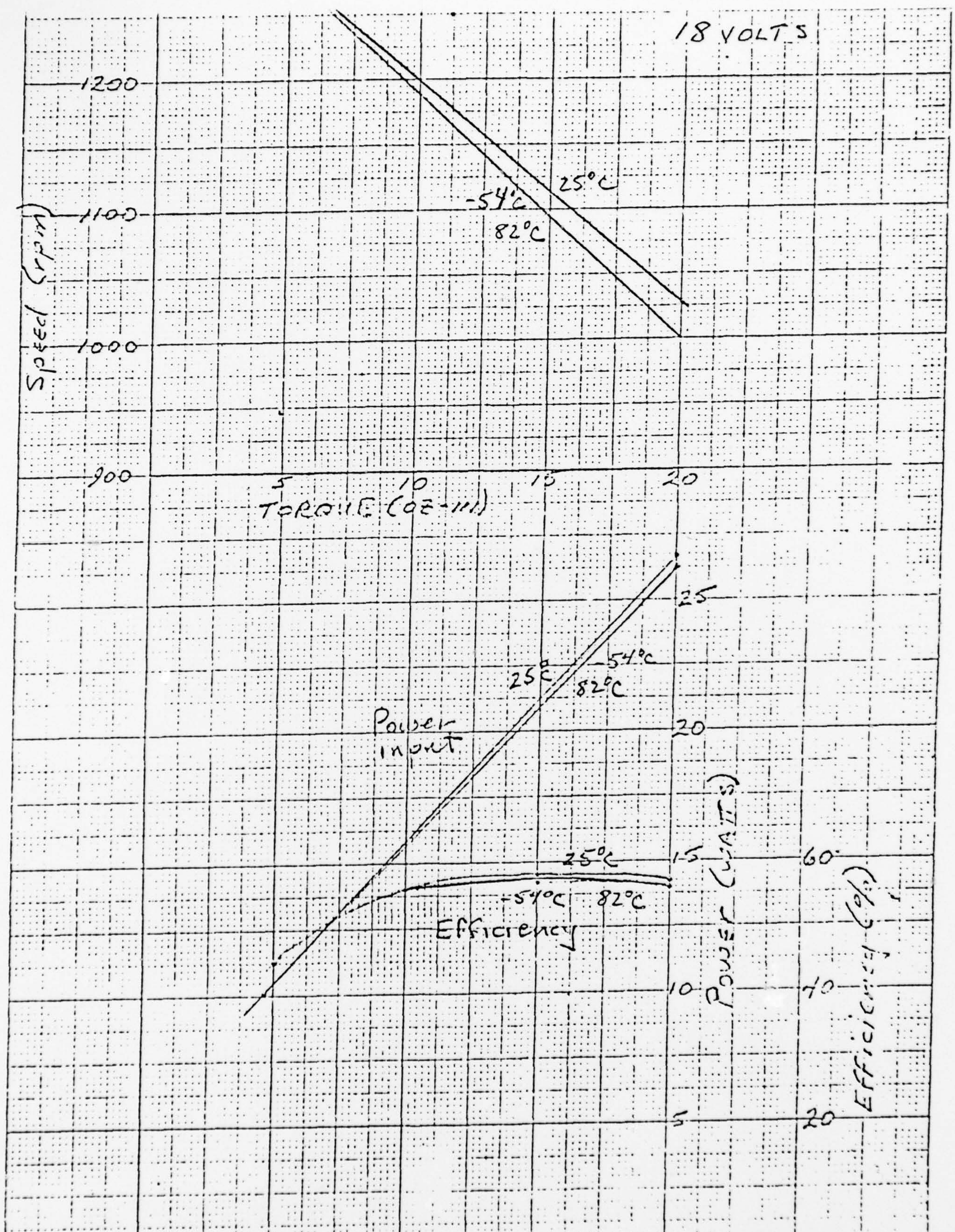
3. With the above changes and the use of several standard integrated circuits which have recently become available, the circuitry can be moved into the motor housing with the attendant advantages of a more convenient package size and fewer leads to seal.

Economic Analysis

The D.C. brushless motor in its current configuration could be delivered in 500 to 1000 piece quantities for a price of approximately $550 each.

If the suggestions given in the conclusions section of this report were followed this price could be reduced to approximately $325 with the expenditure of approximately $20,000 non-recurring engineering effort.

The circuit size could also be further reduced using hybrid curcuit technology. The item cost in this approach (using MIL-STD-883 hybrid circuits) would be about $660. This would require a non-recurring charge at about $20,000.



18 VOLTS
1200
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Speed (rpm)
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TORQUE (OZ-IN)
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-54°C
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82°C
Power input
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POWER (WATTS)
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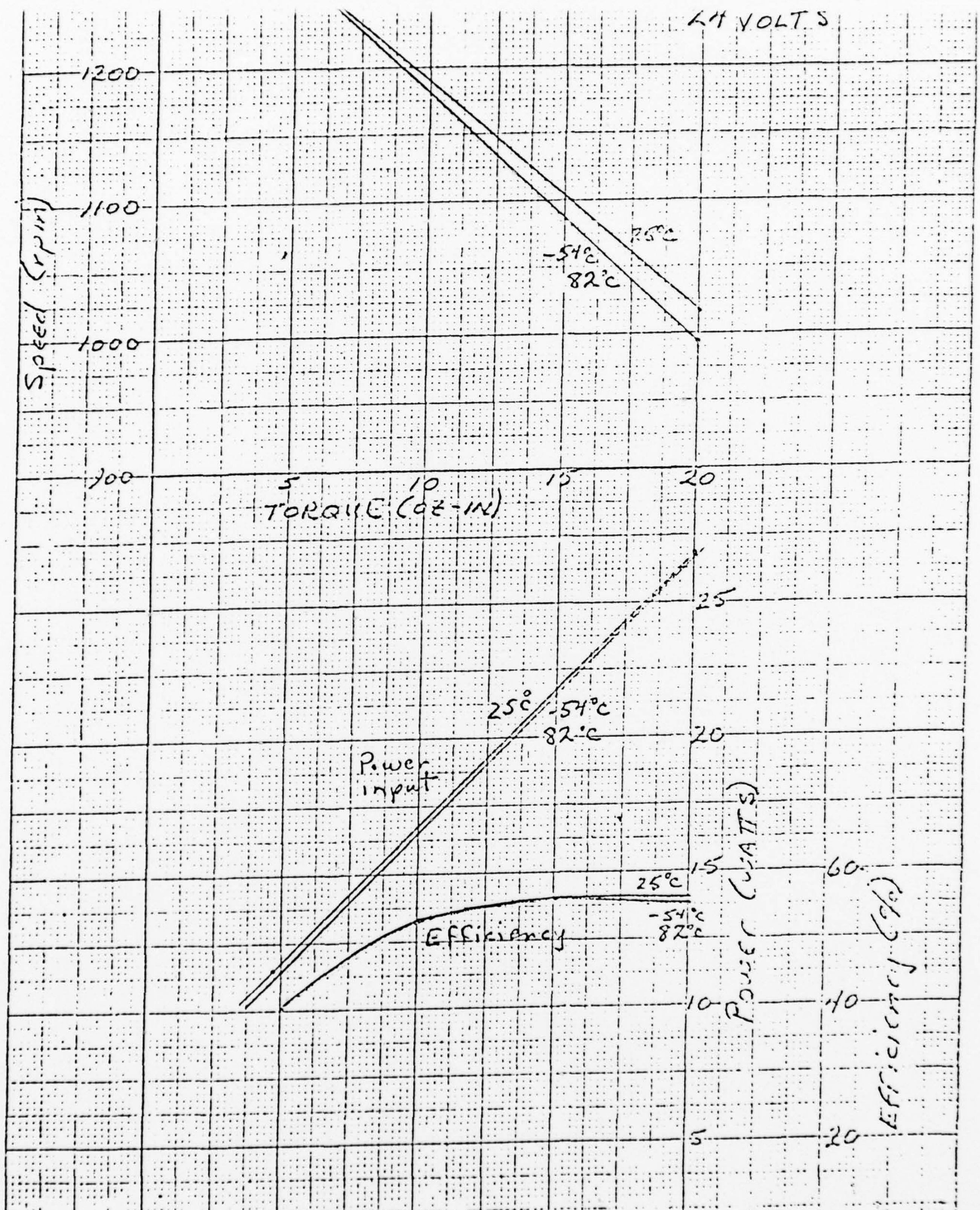
Efficiency (%)
25°C
-54°C
82°C
Efficiency



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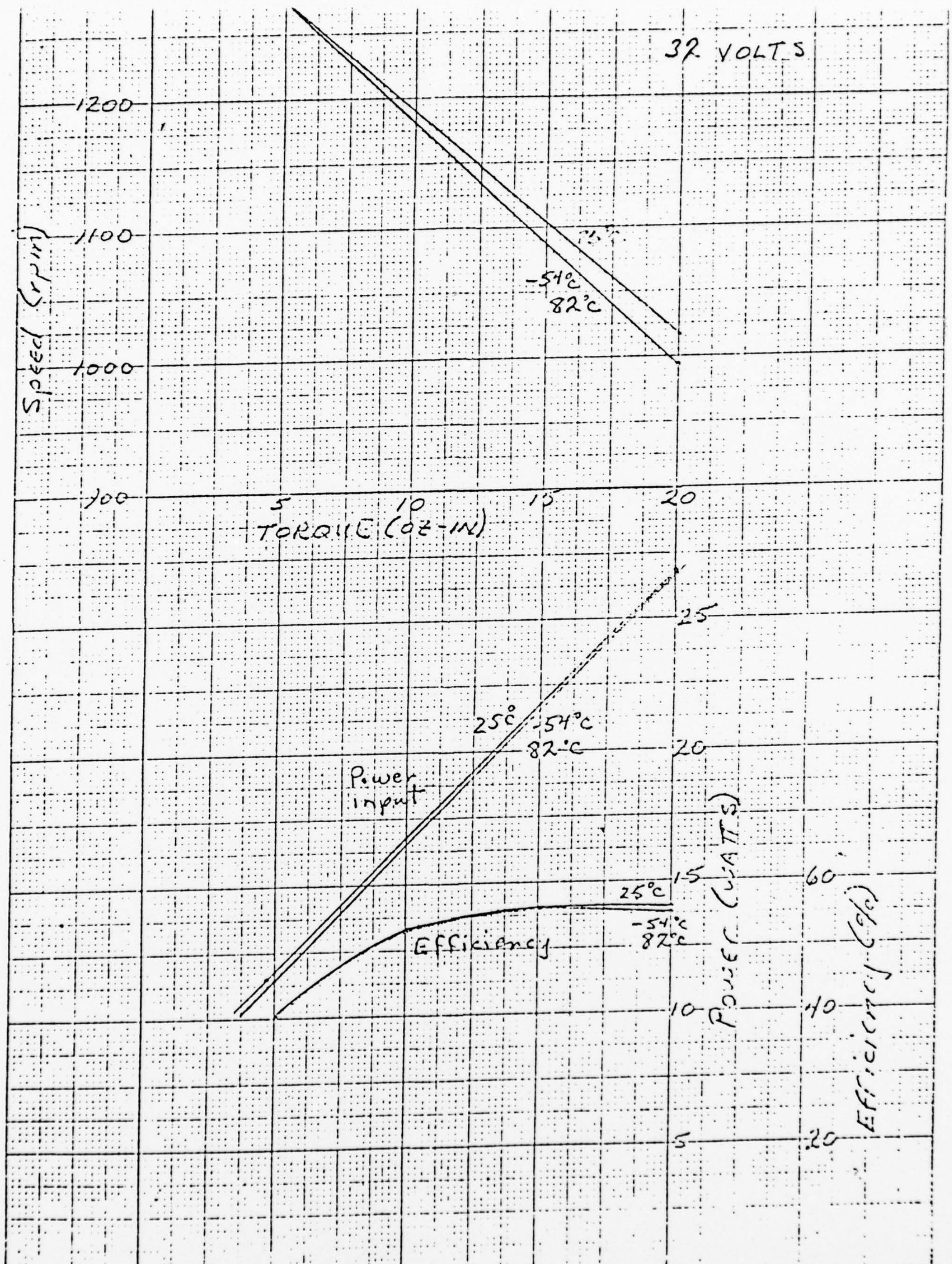

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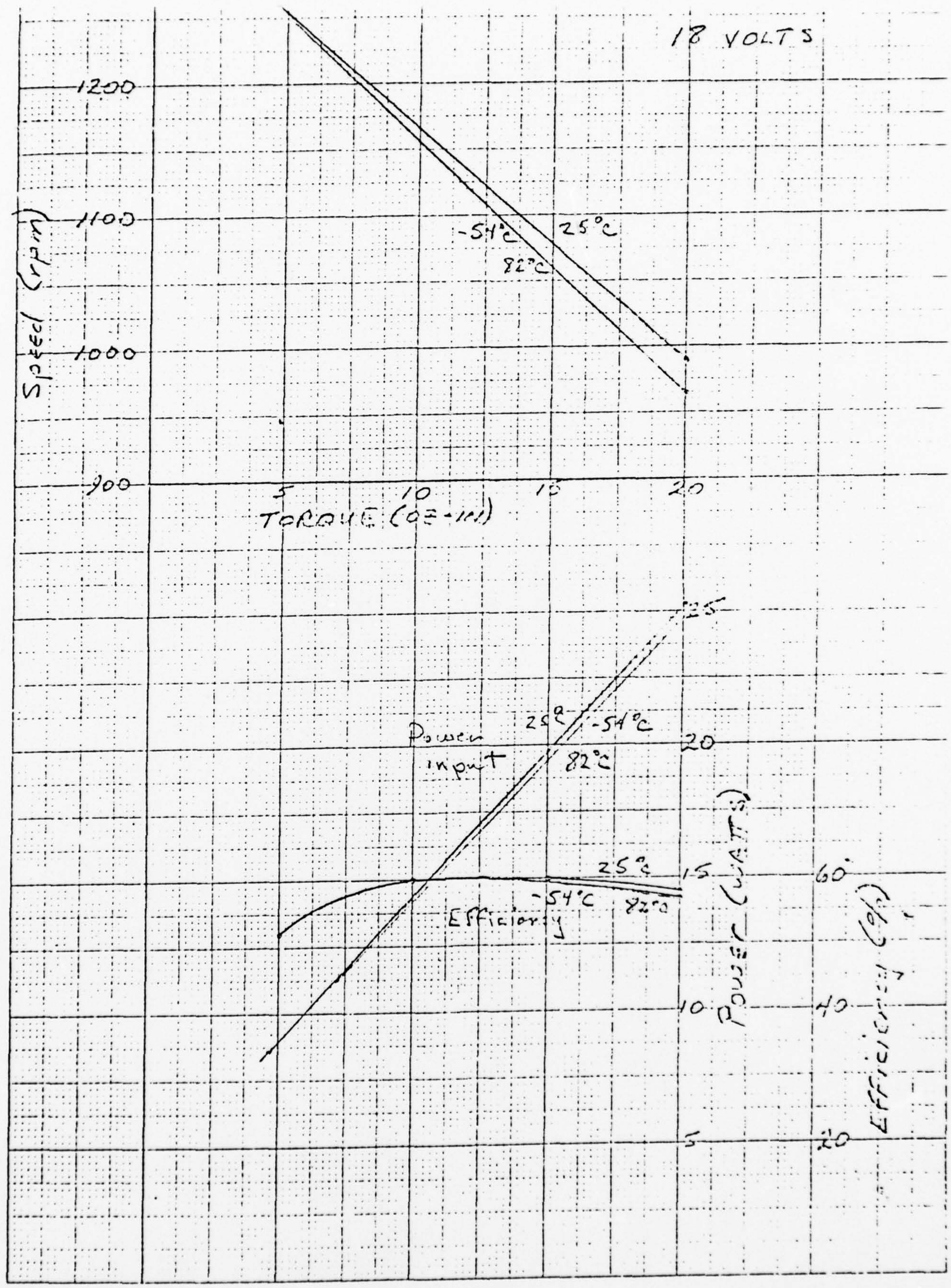

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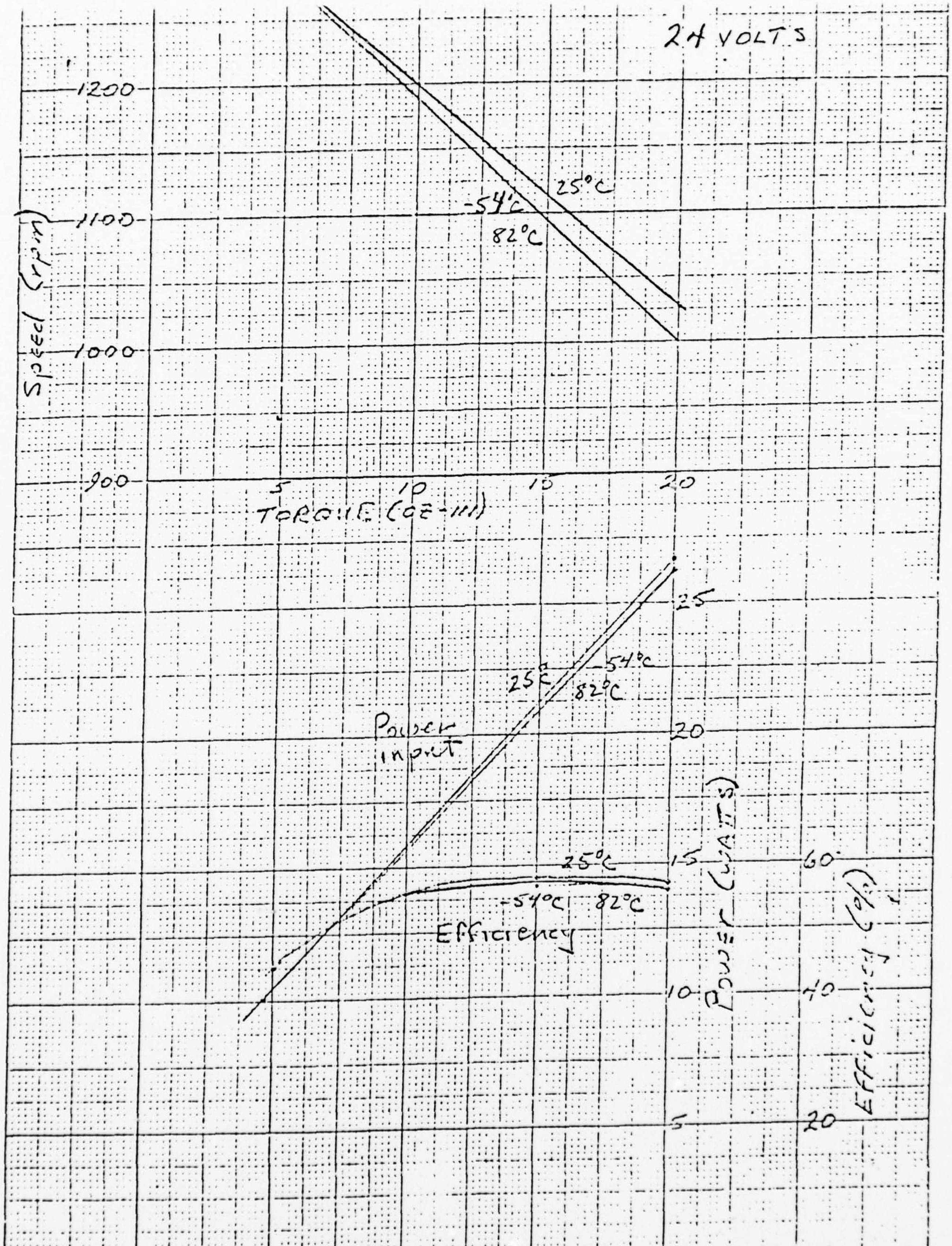

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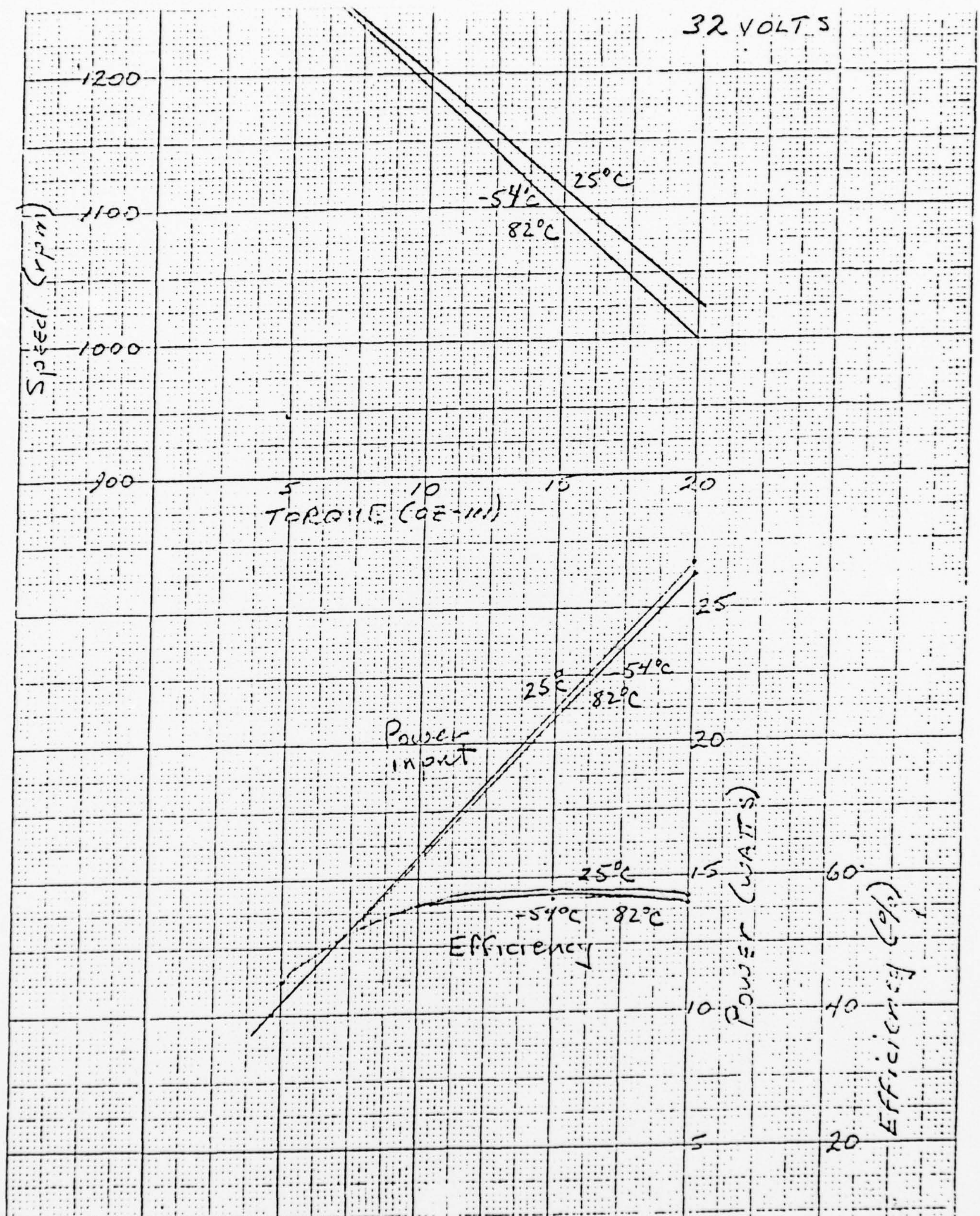
Efficiency (%)



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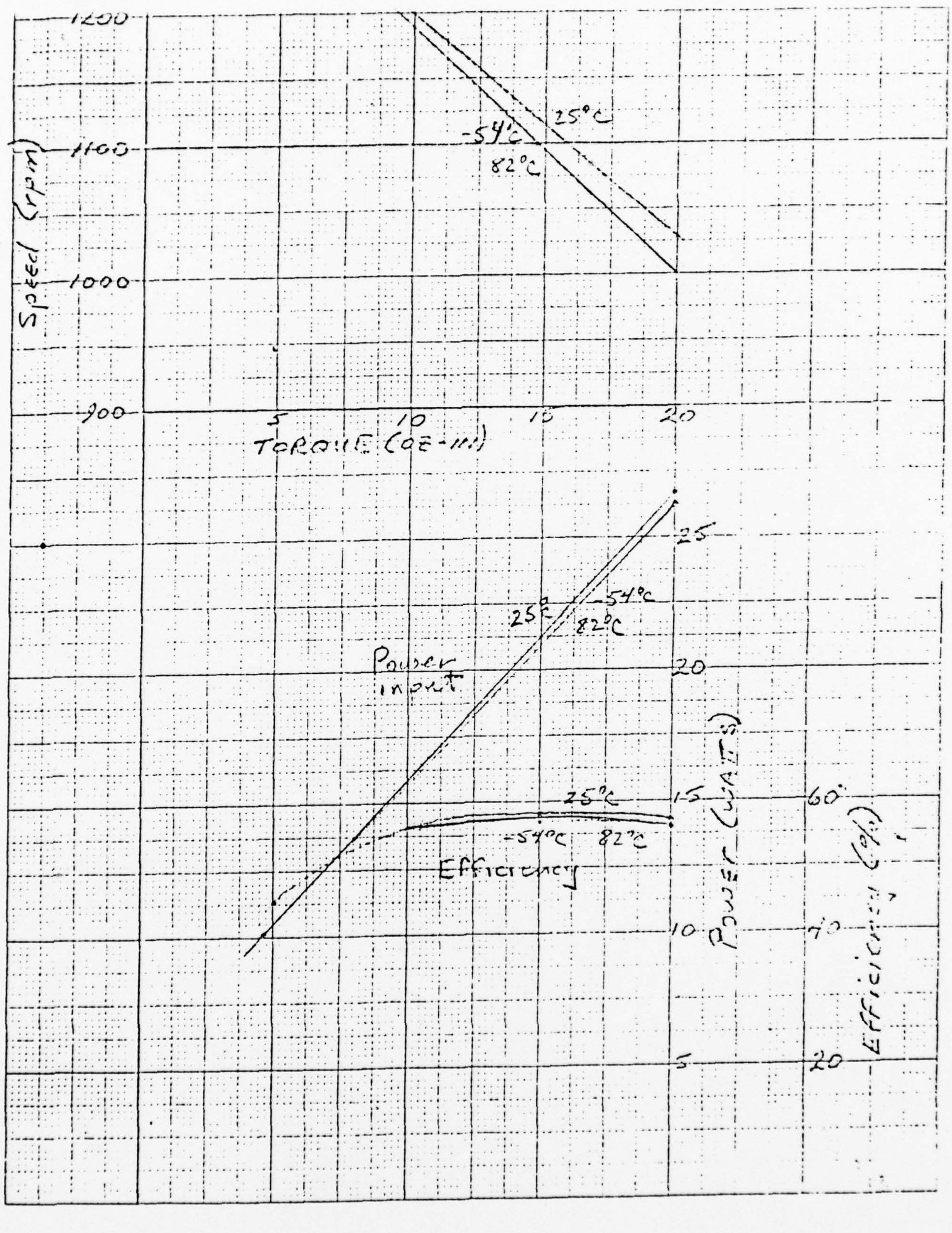
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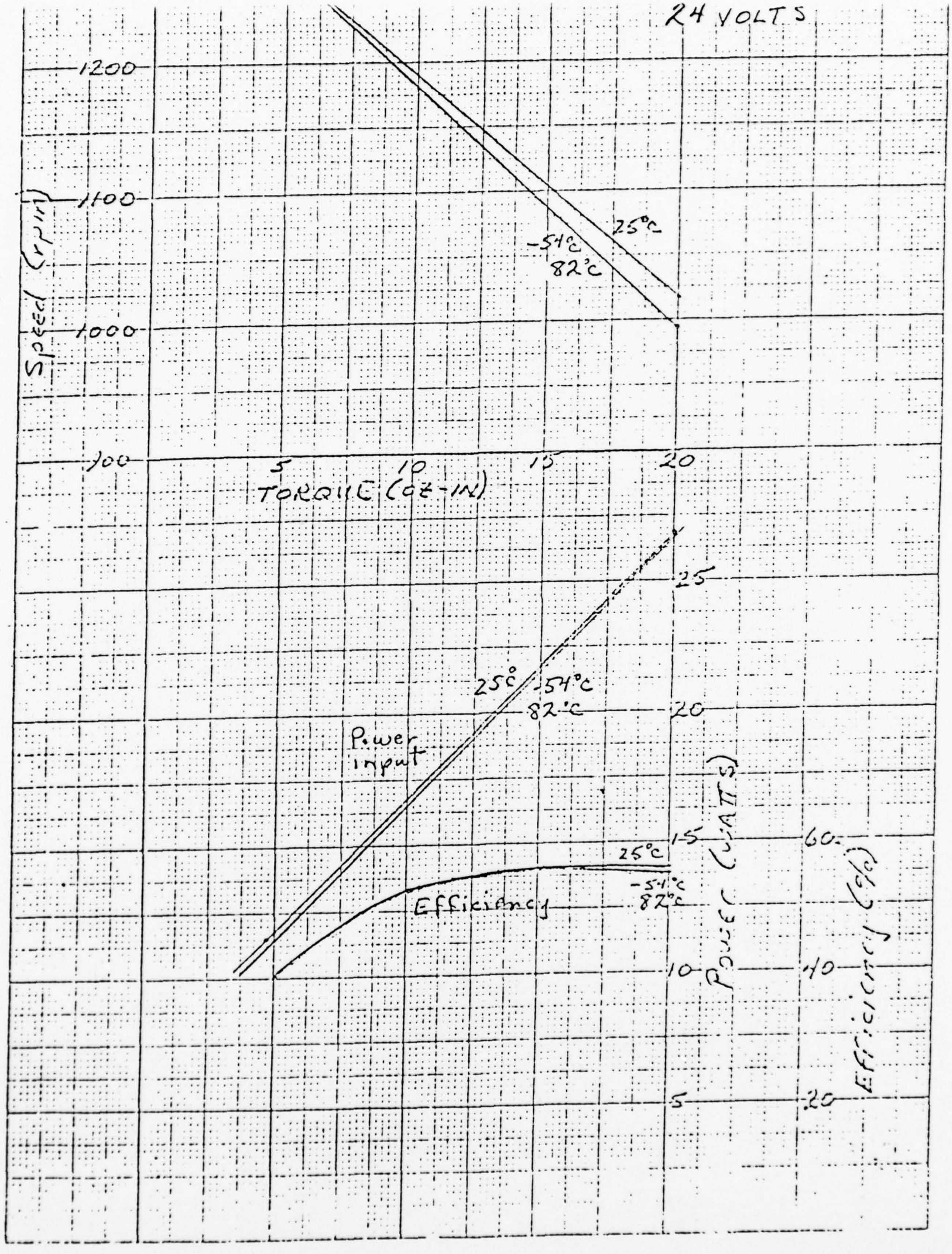
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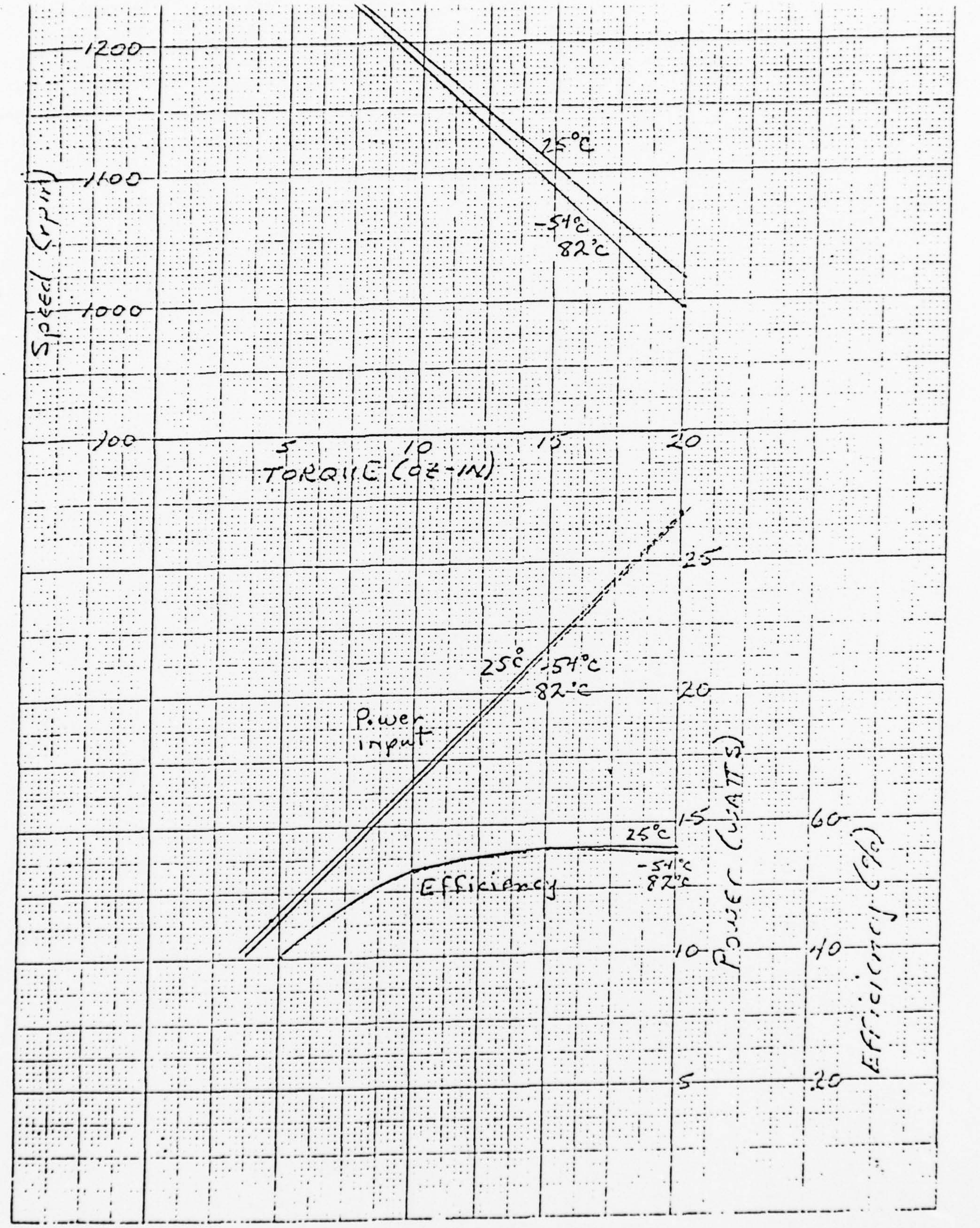

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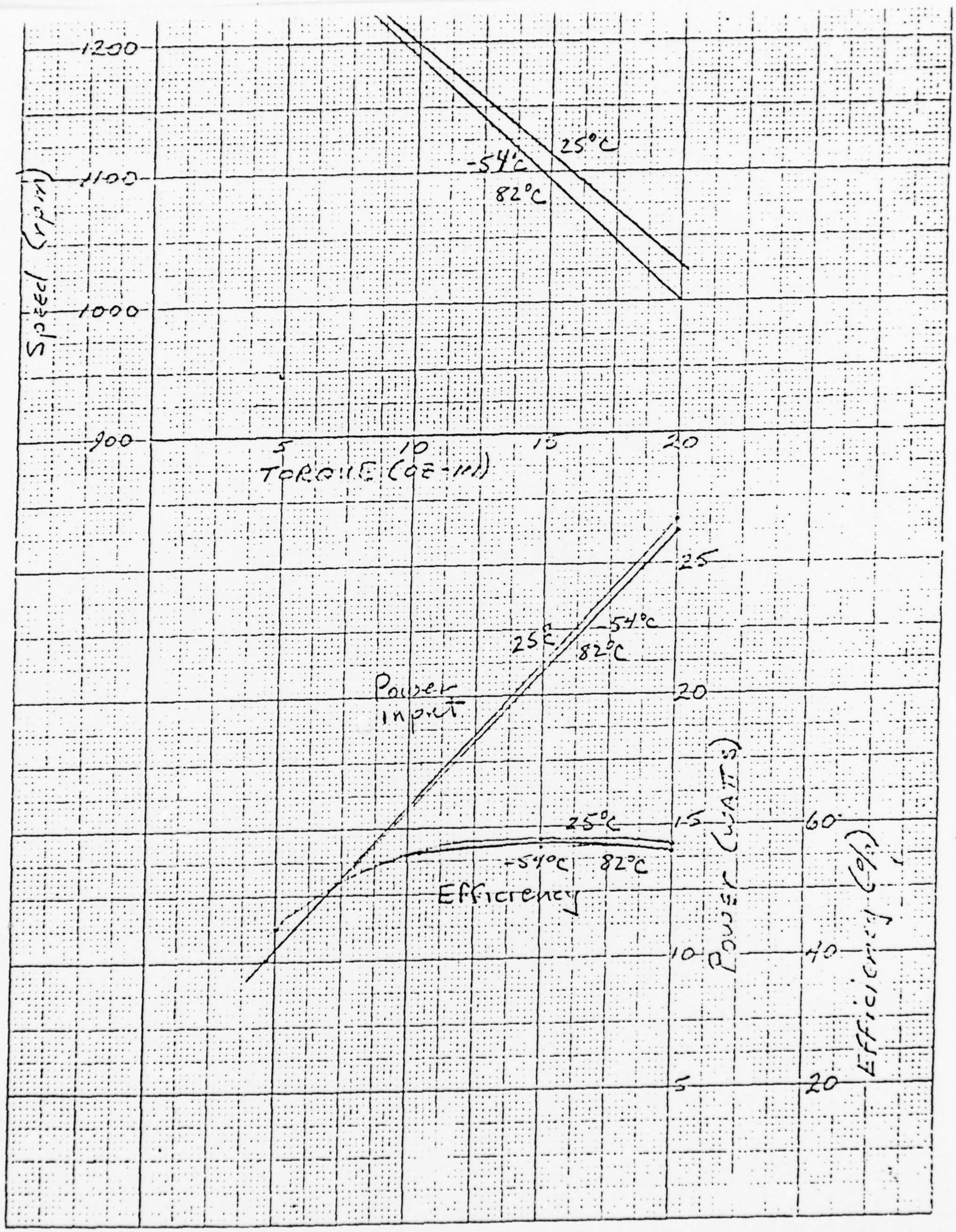

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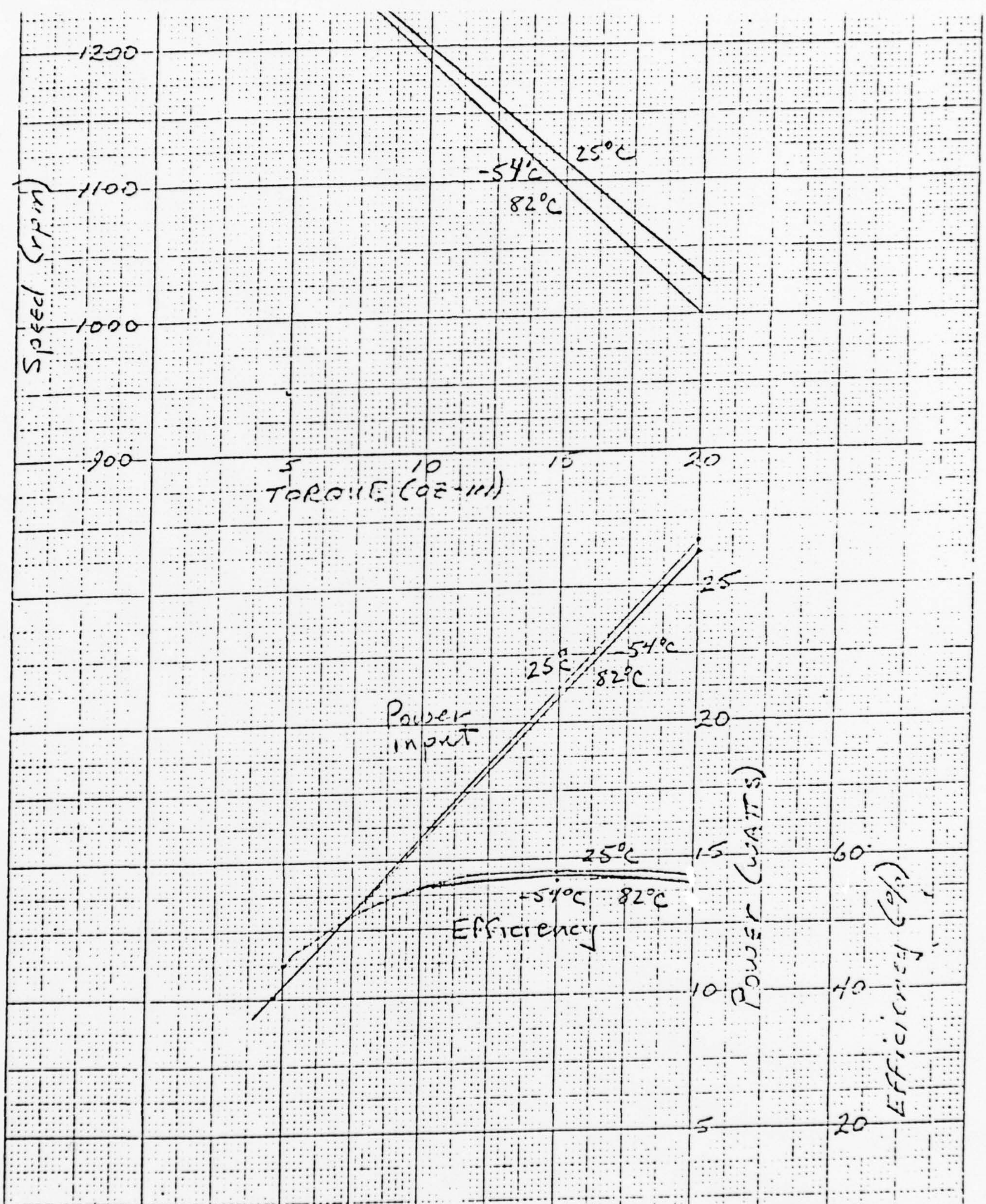

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TORQUE (OZ-IN)
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Power input
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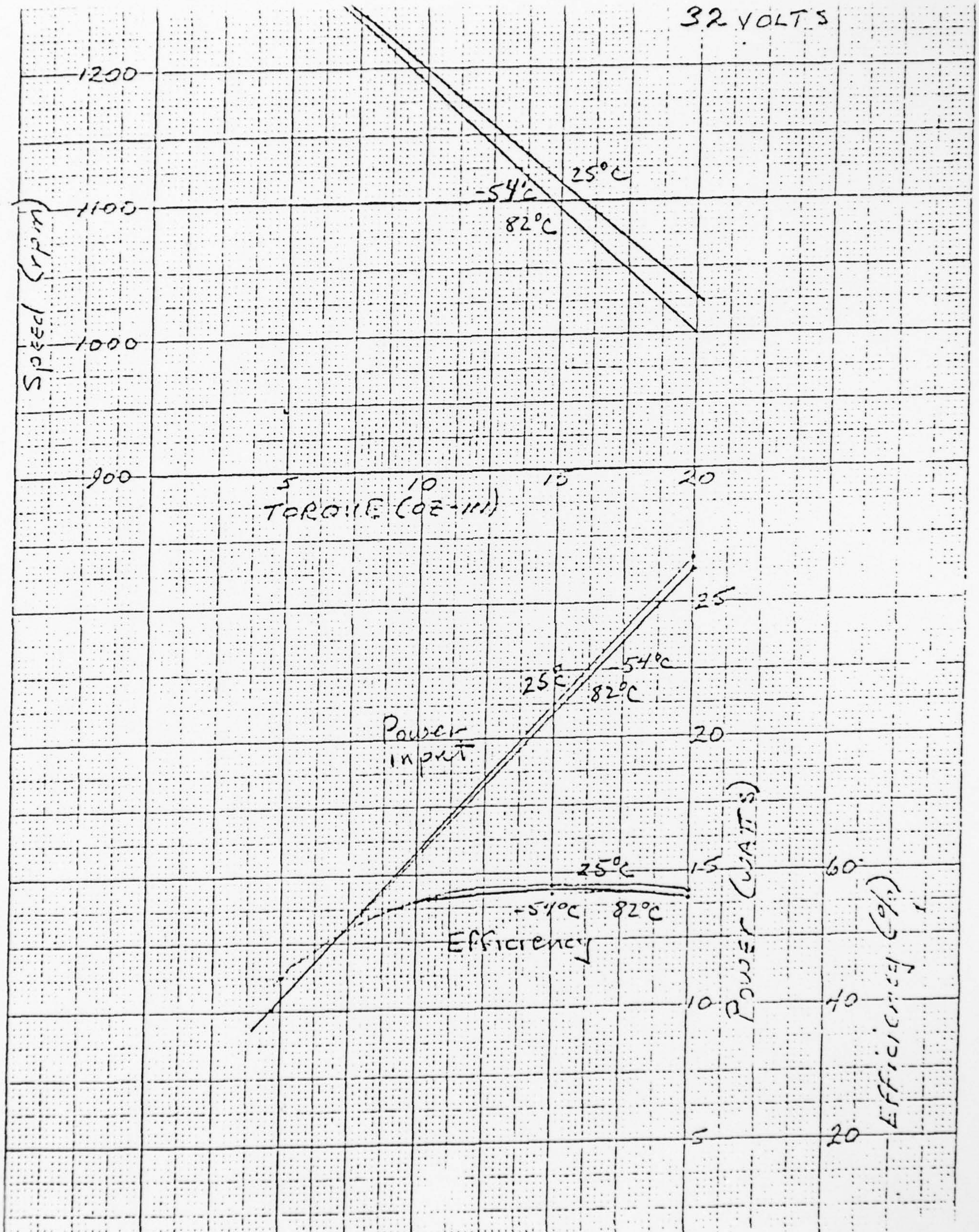
POWER (WATTS)
Efficiency (%)



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1200
1100
1000
900
Speed (rpm)
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-54°C
82°C
5
10
15
20
TORQUE (OZ-IN)
Power input
25°C
-54°C
82°C
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10
5
Power (WATTS)
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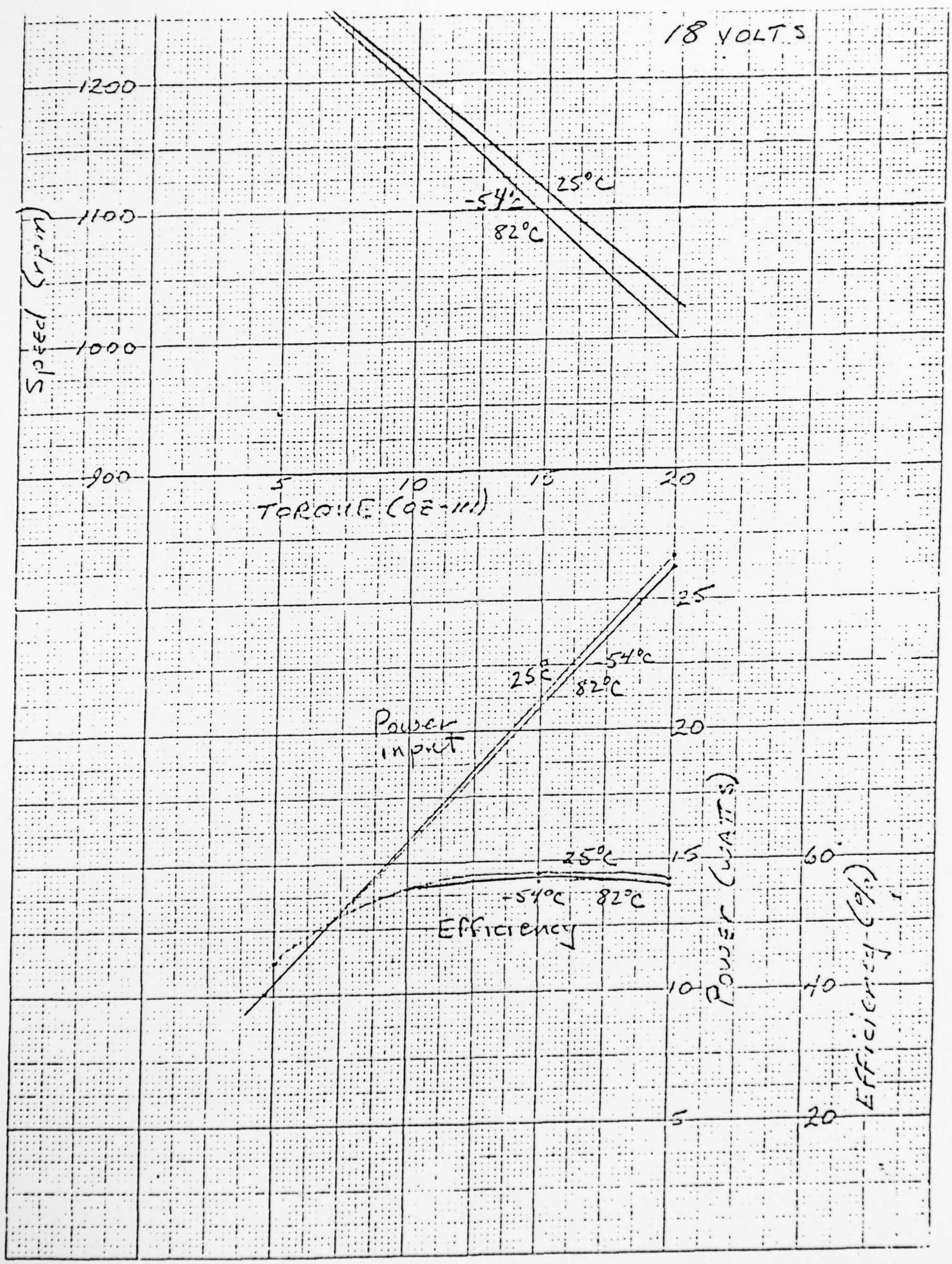
Efficiency (%)
25°C
-54°C
82°C
Efficiency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900
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82°C
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15
20
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Efficiency
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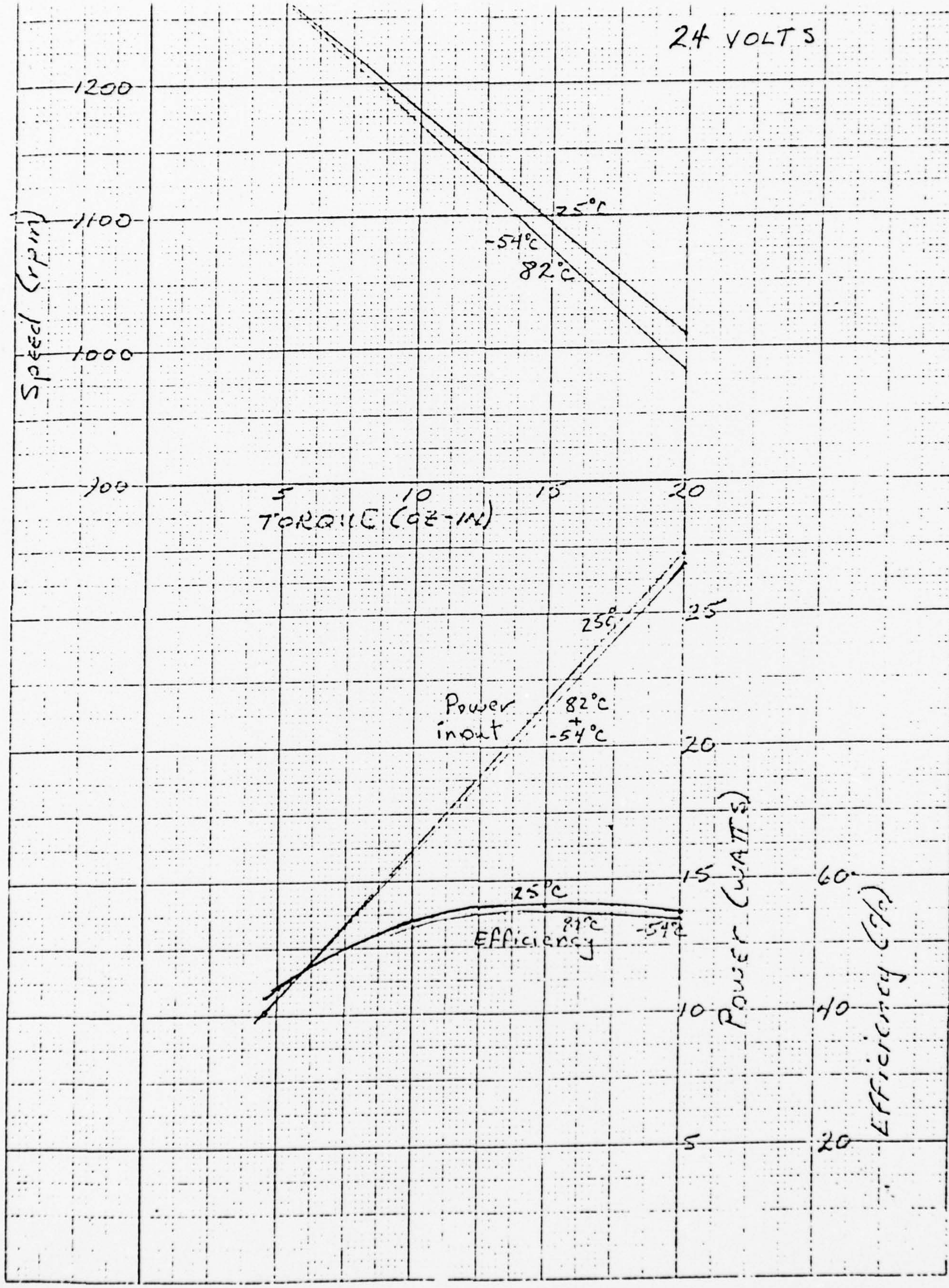
40
5
20
POWER (WATTS)
Efficiency (%)



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Speed (rpm)
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TORQUE (OZ-IN)
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Efficiency (%)
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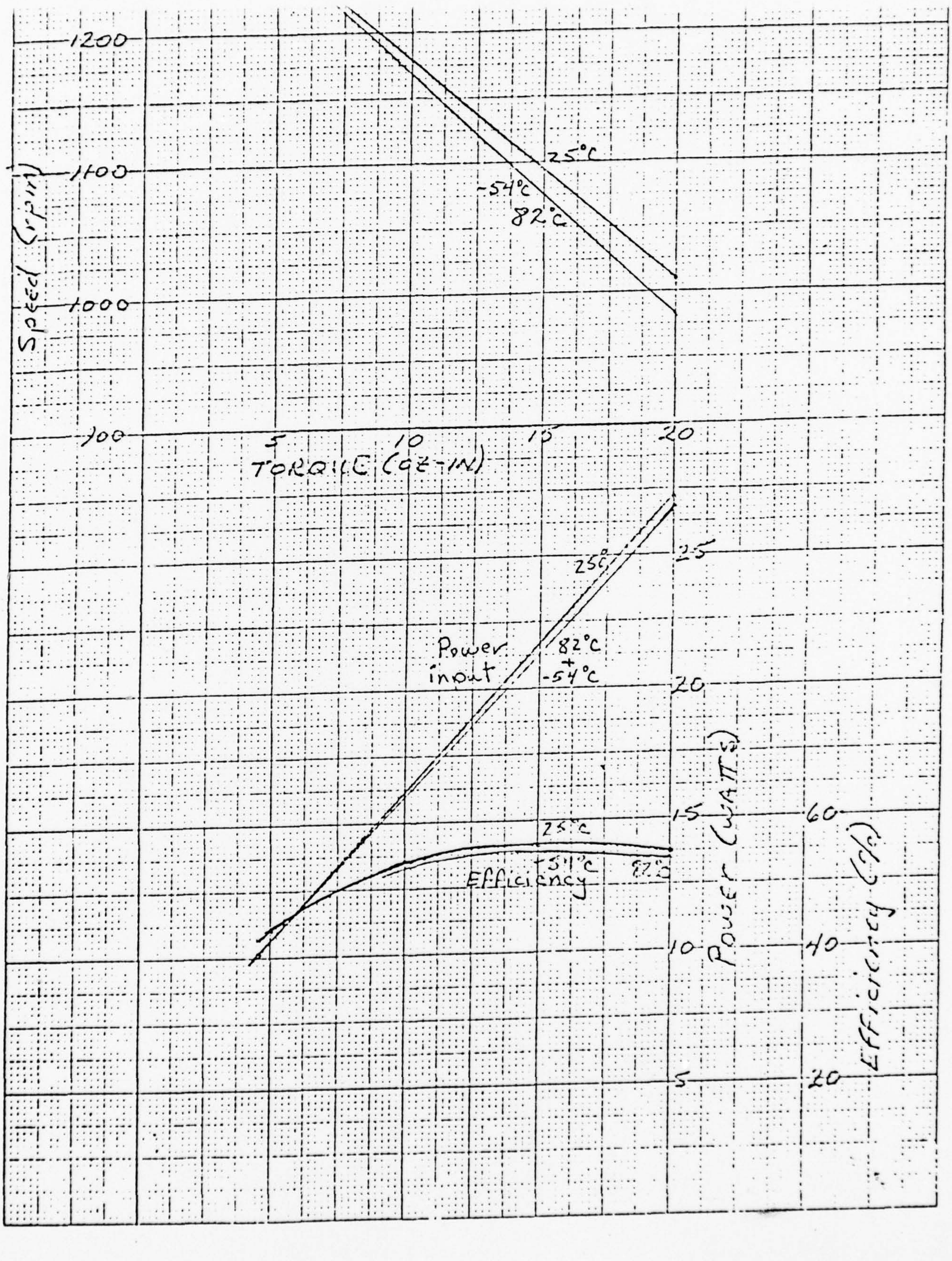
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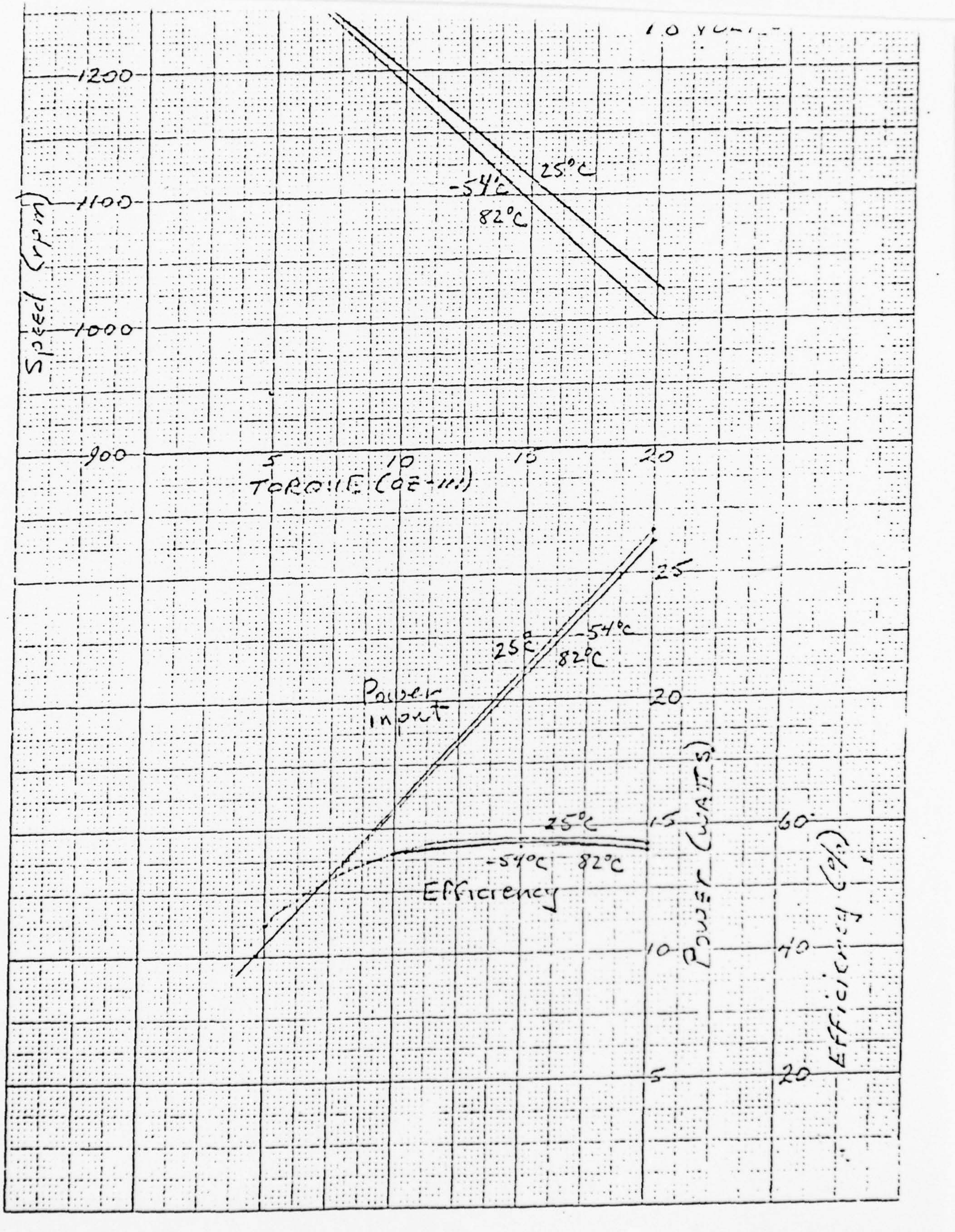
Efficiency (%)



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Speed (rpm)
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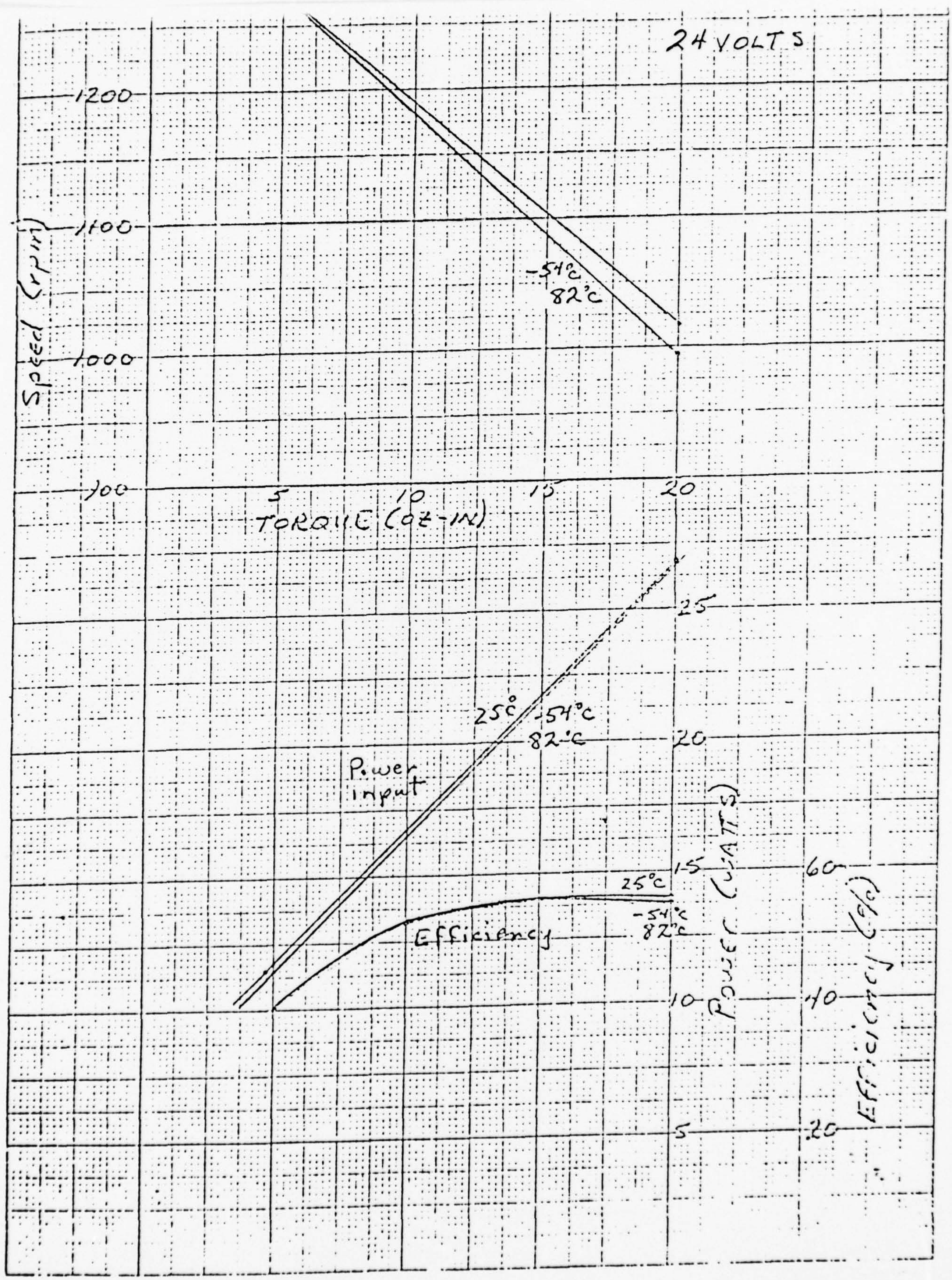
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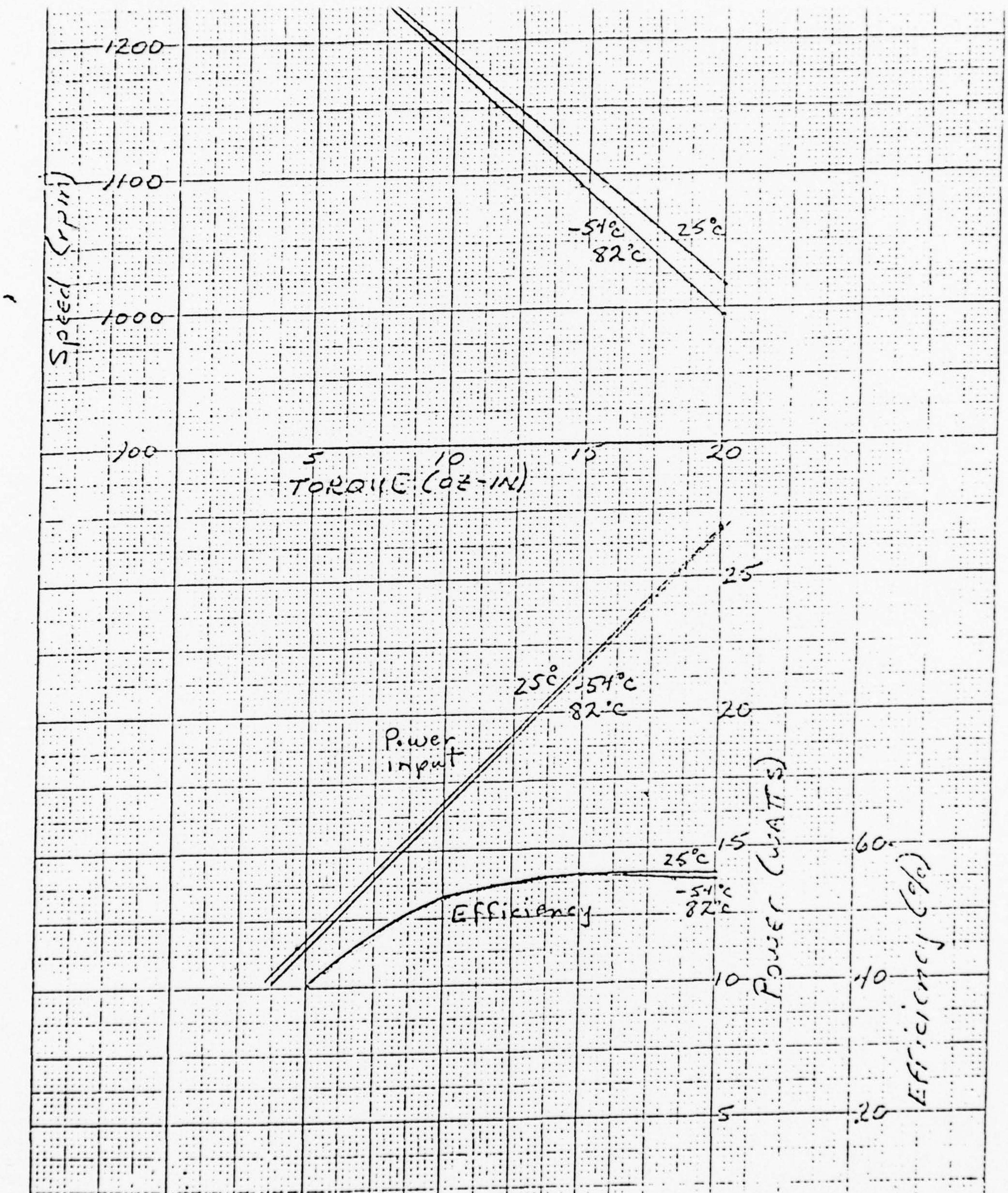

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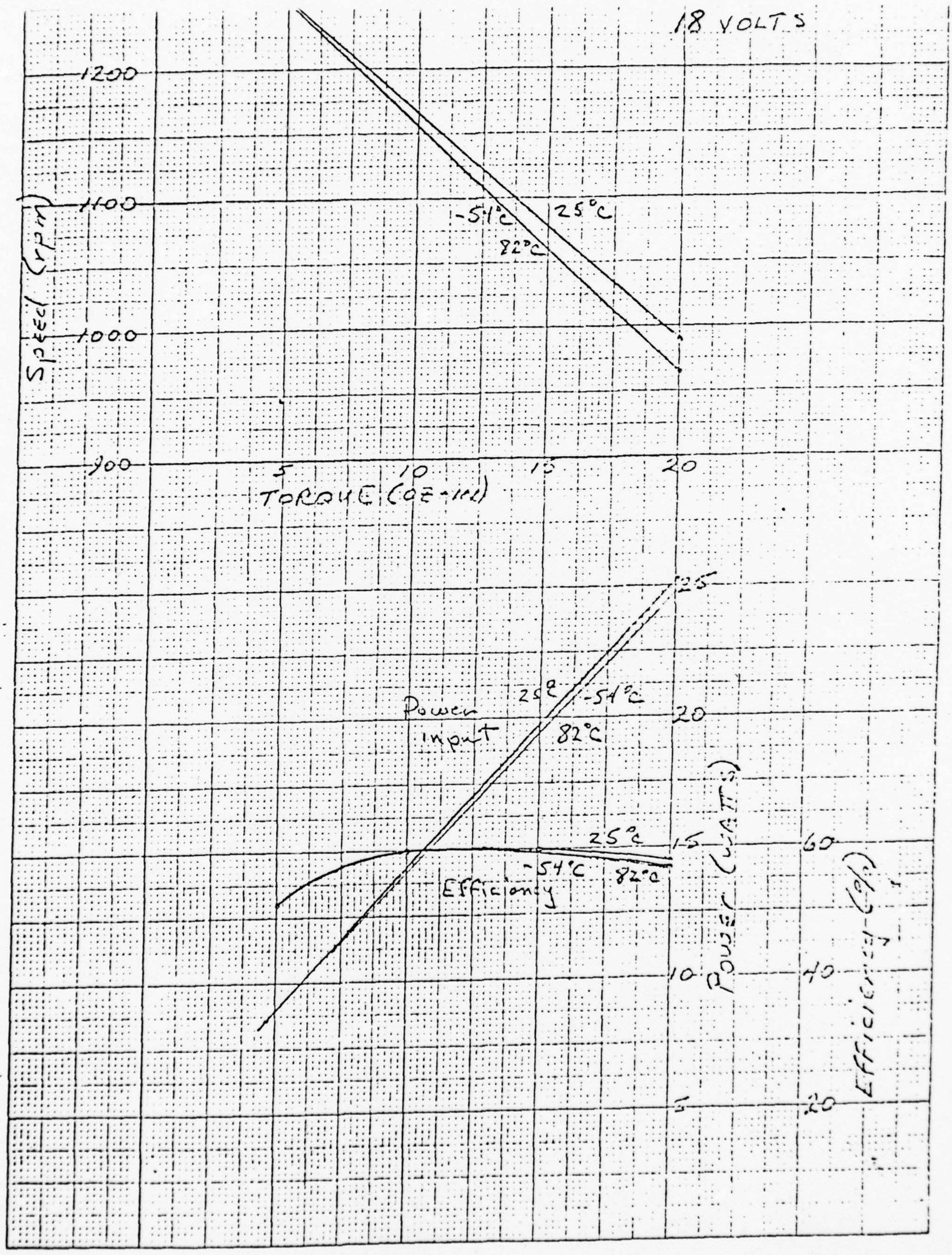
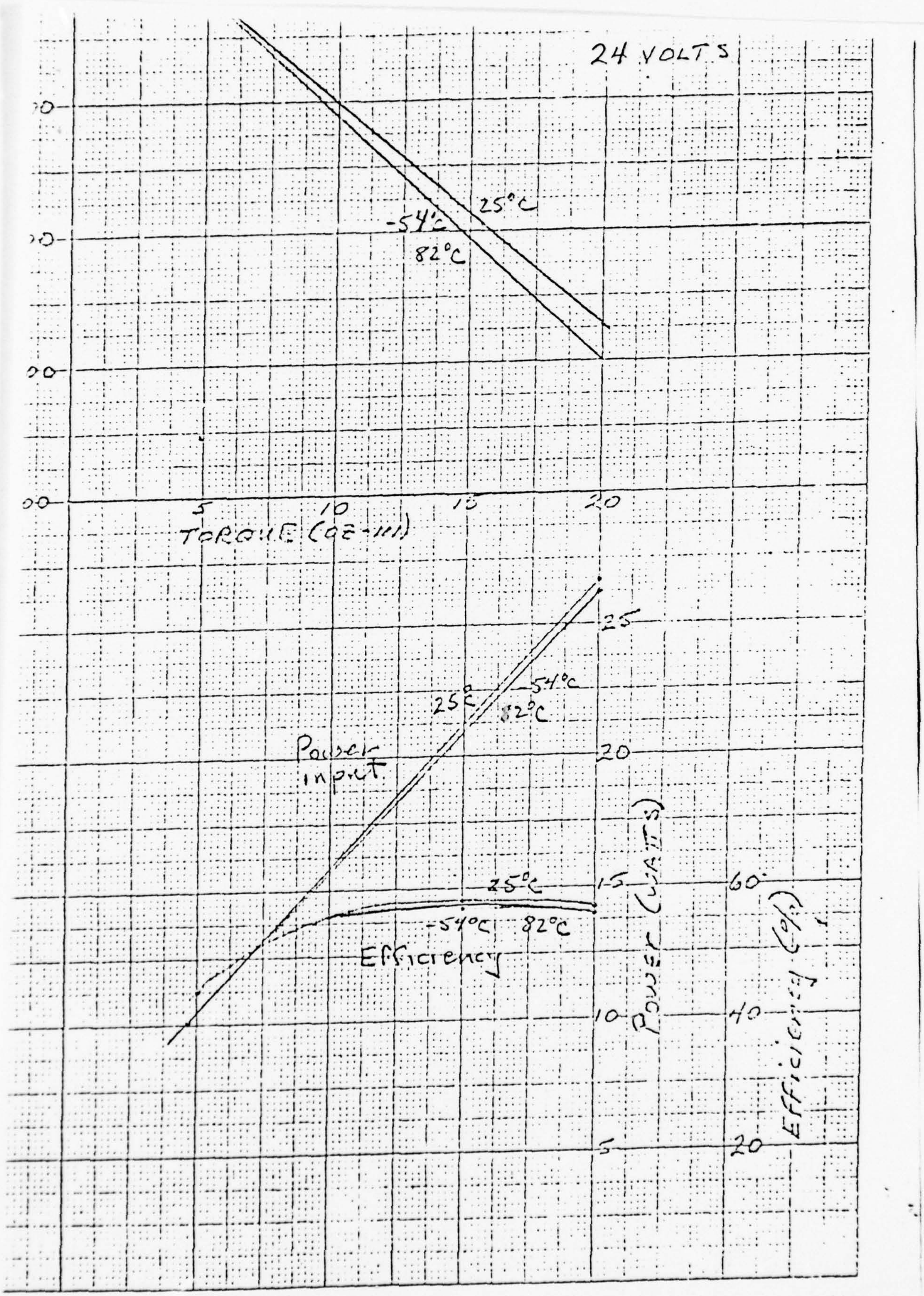
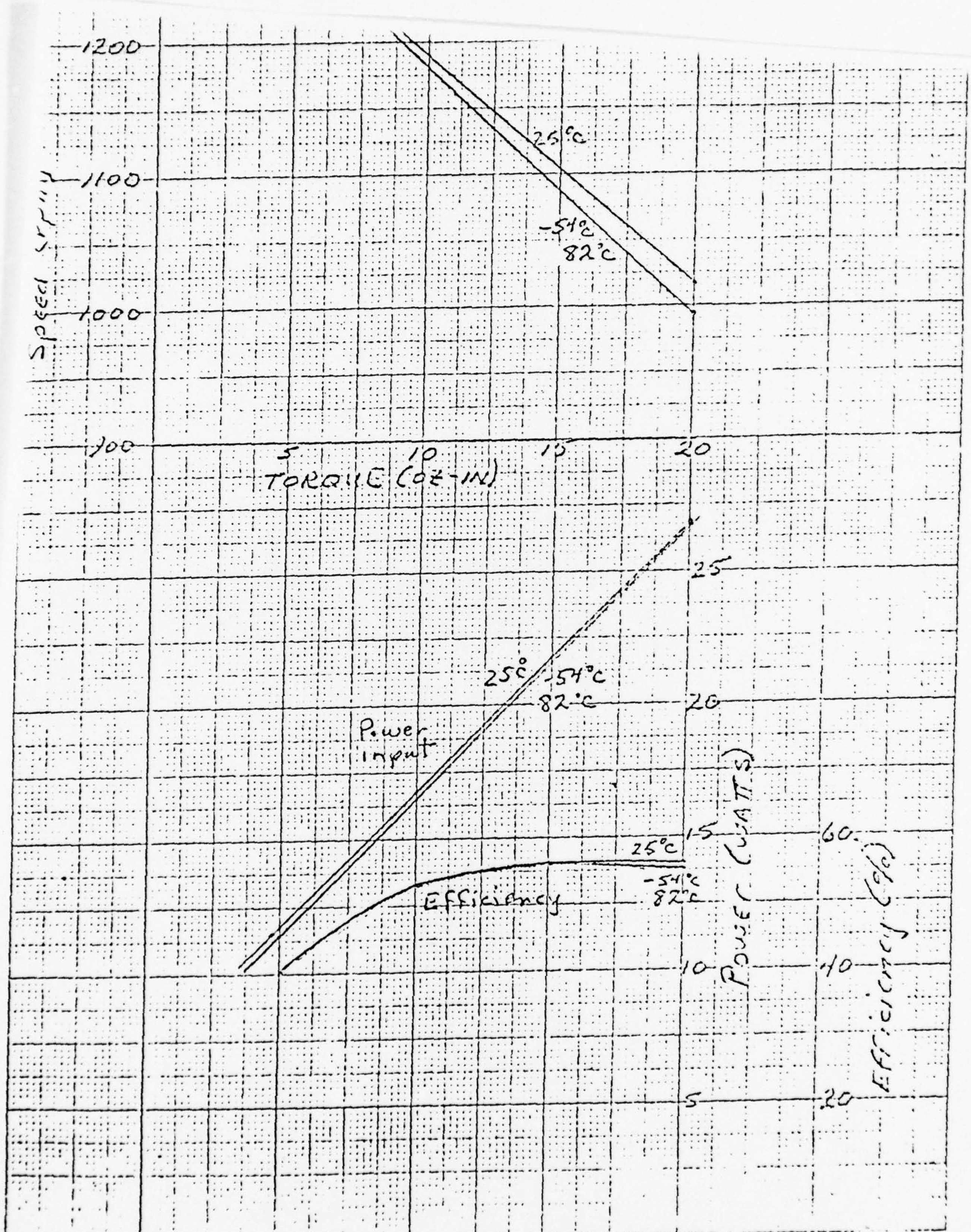
82°C
Efficiency
POWER (WATTS)
60
40
20
Efficiency (%)

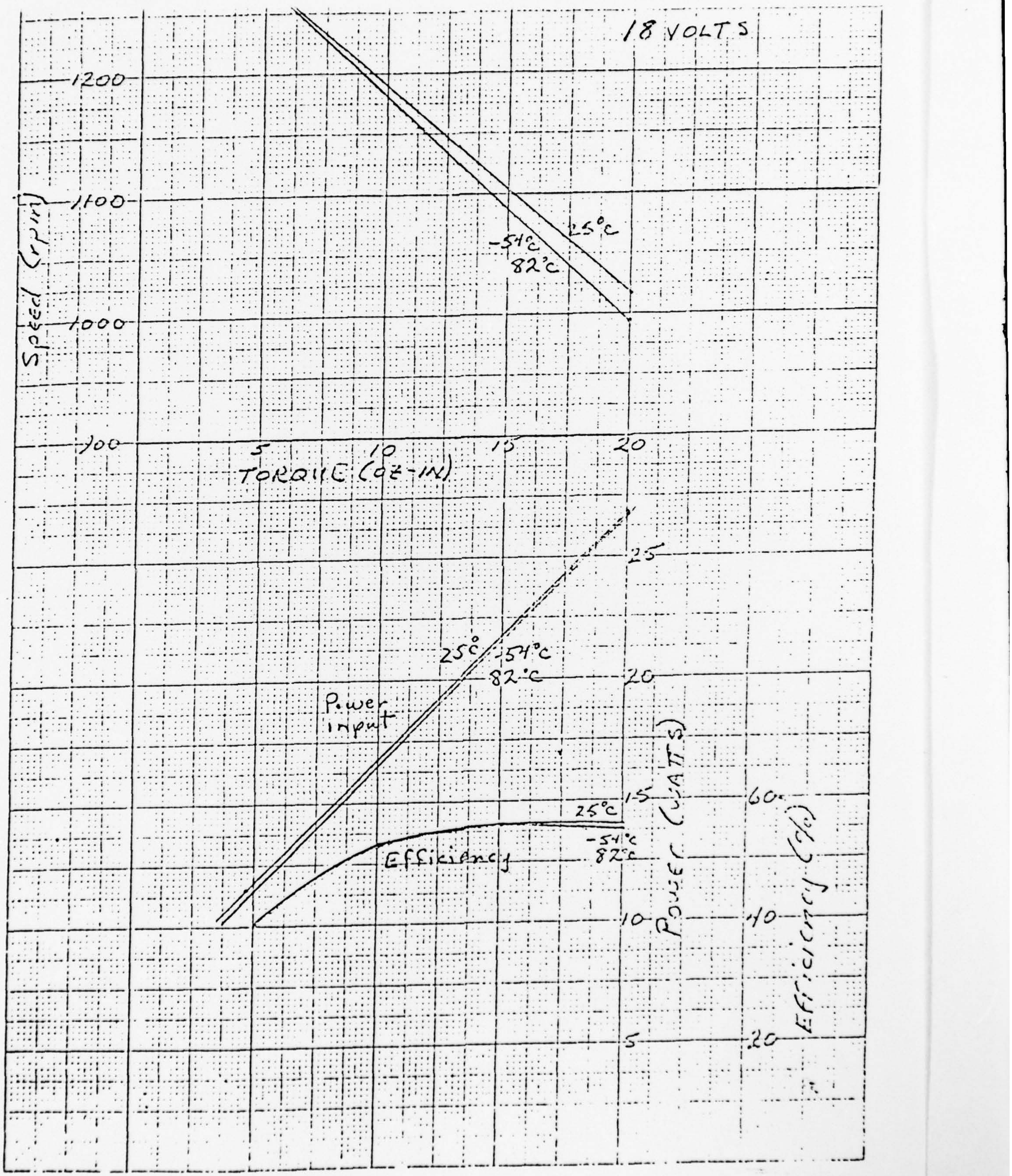


18 VOLTS
Speed (rpm)
1200
1100
1000
900
-54°C
25°C
82°C
5
10
15
20
TORQUE (OZ-IN)
25
20
15
10
5
Power input
25°C
-54°C
82°C
Efficiency
POWER (WATTS)
60
40
20
Efficiency (%)

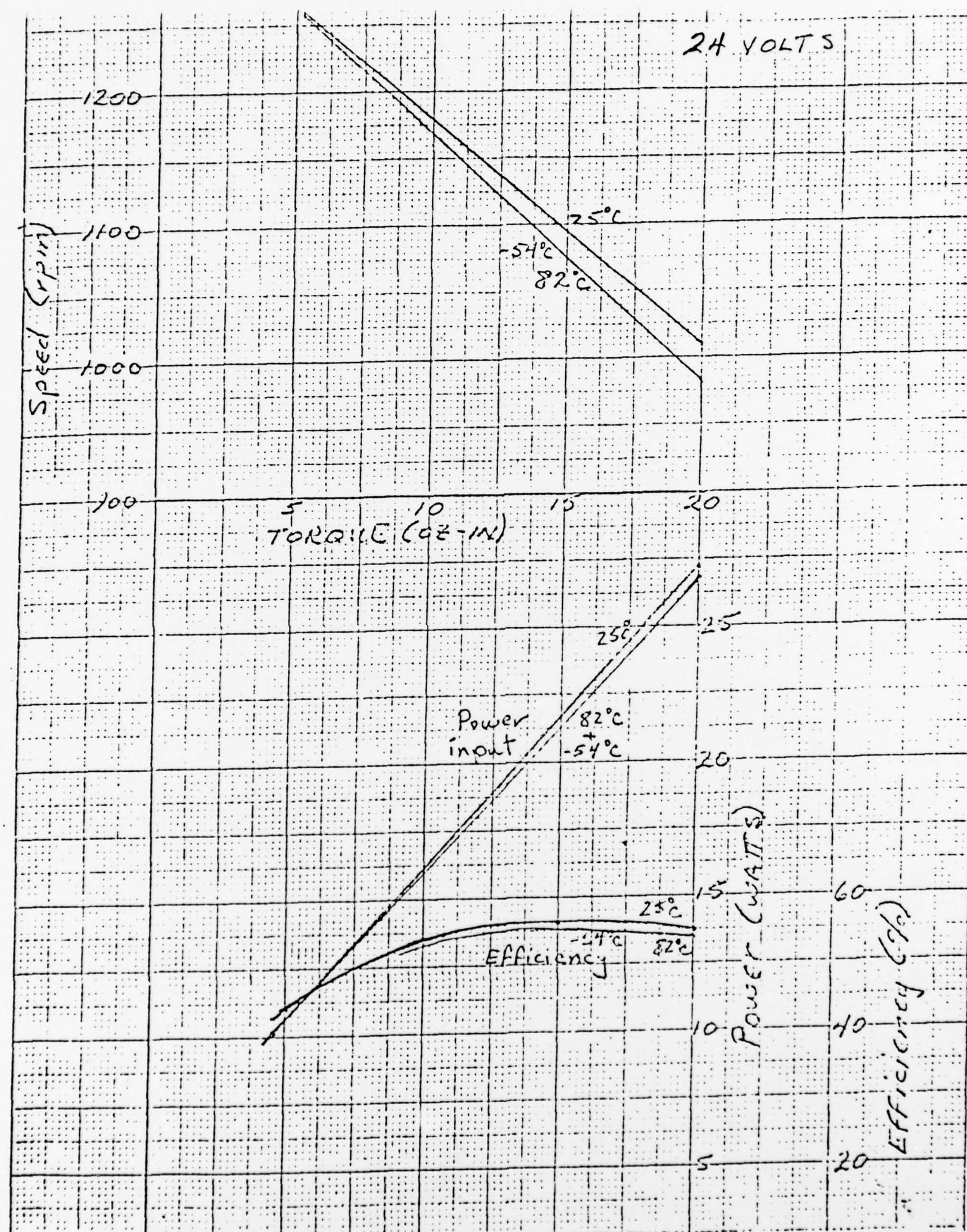

24 VOLTS
25°C
-54°C
82°C
5
10
15
20
TORQUE (OZ-IN)
25
-54°C
25°C
82°C
Power input
20
15
25°C
-54°C
82°C
Efficiency
10
5
POWER (WATTS)
60
40
20
Efficiency (%)

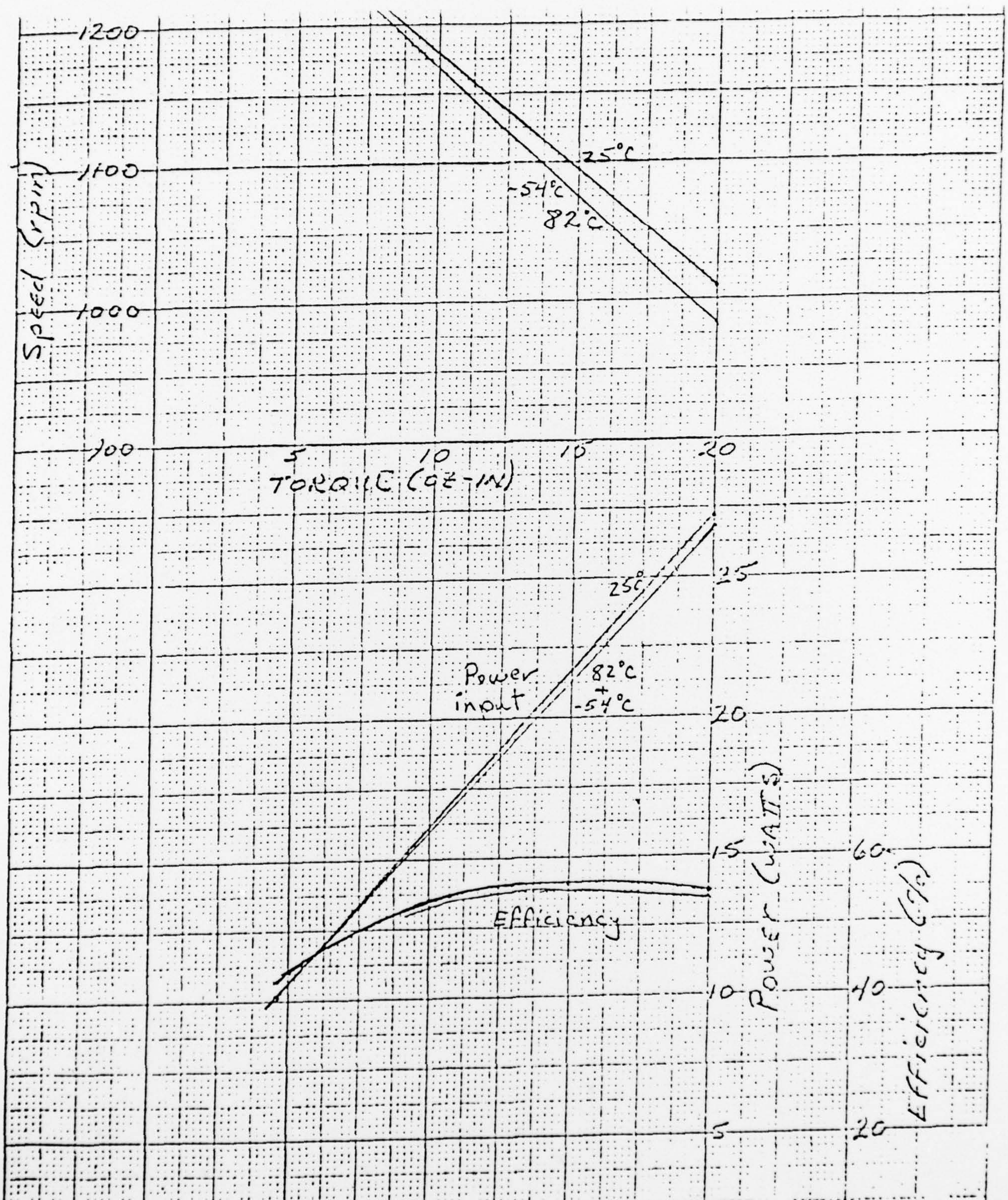


Speed
1200
1100
1000
5
10
15
20
TORQUE (OZ-IN)
25°C
-54°C
82°C
Power input
Efficiency
25
20
15
10
5
60
40
20
POWER (WATTS)
Efficiency (%)

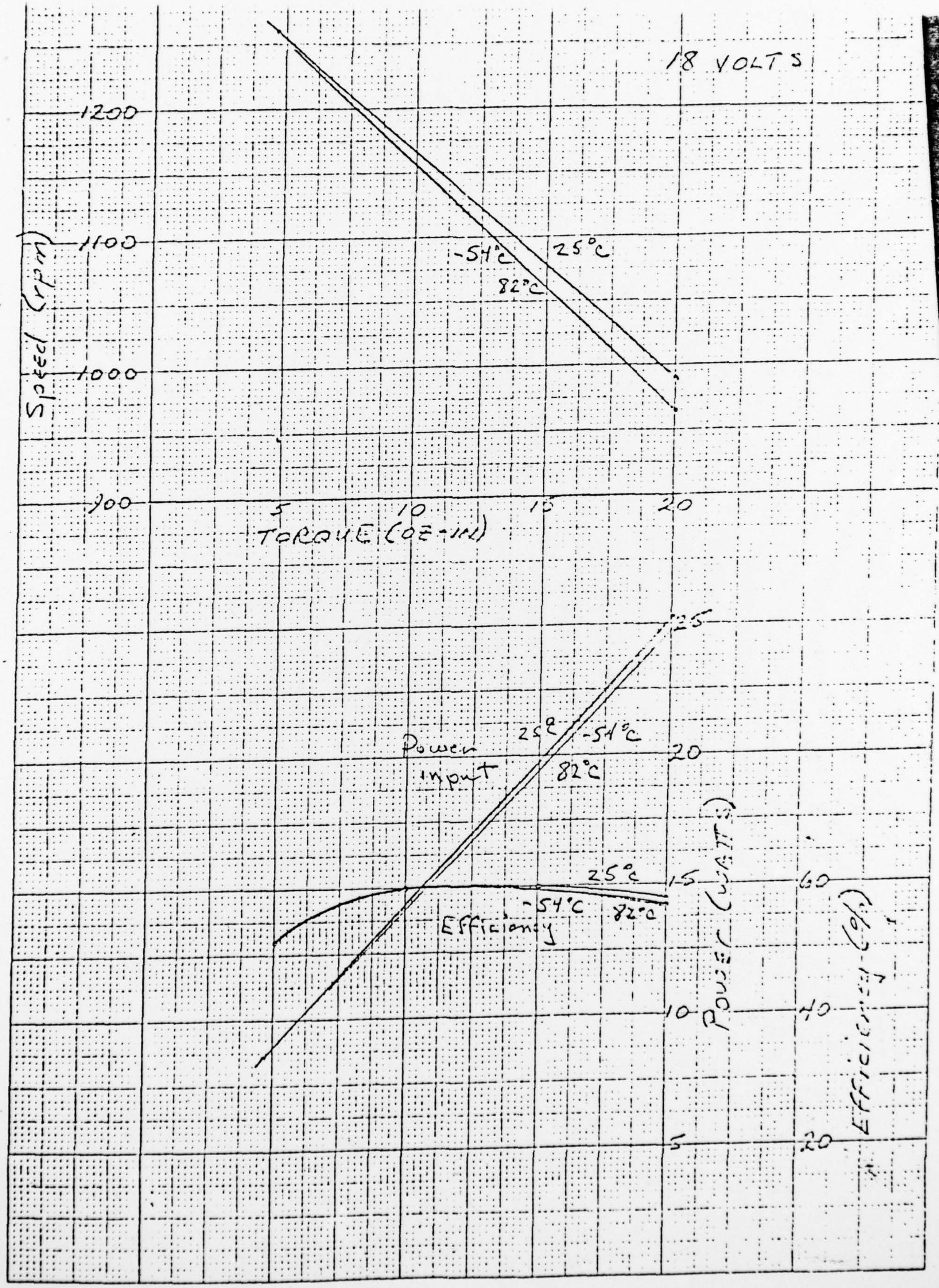


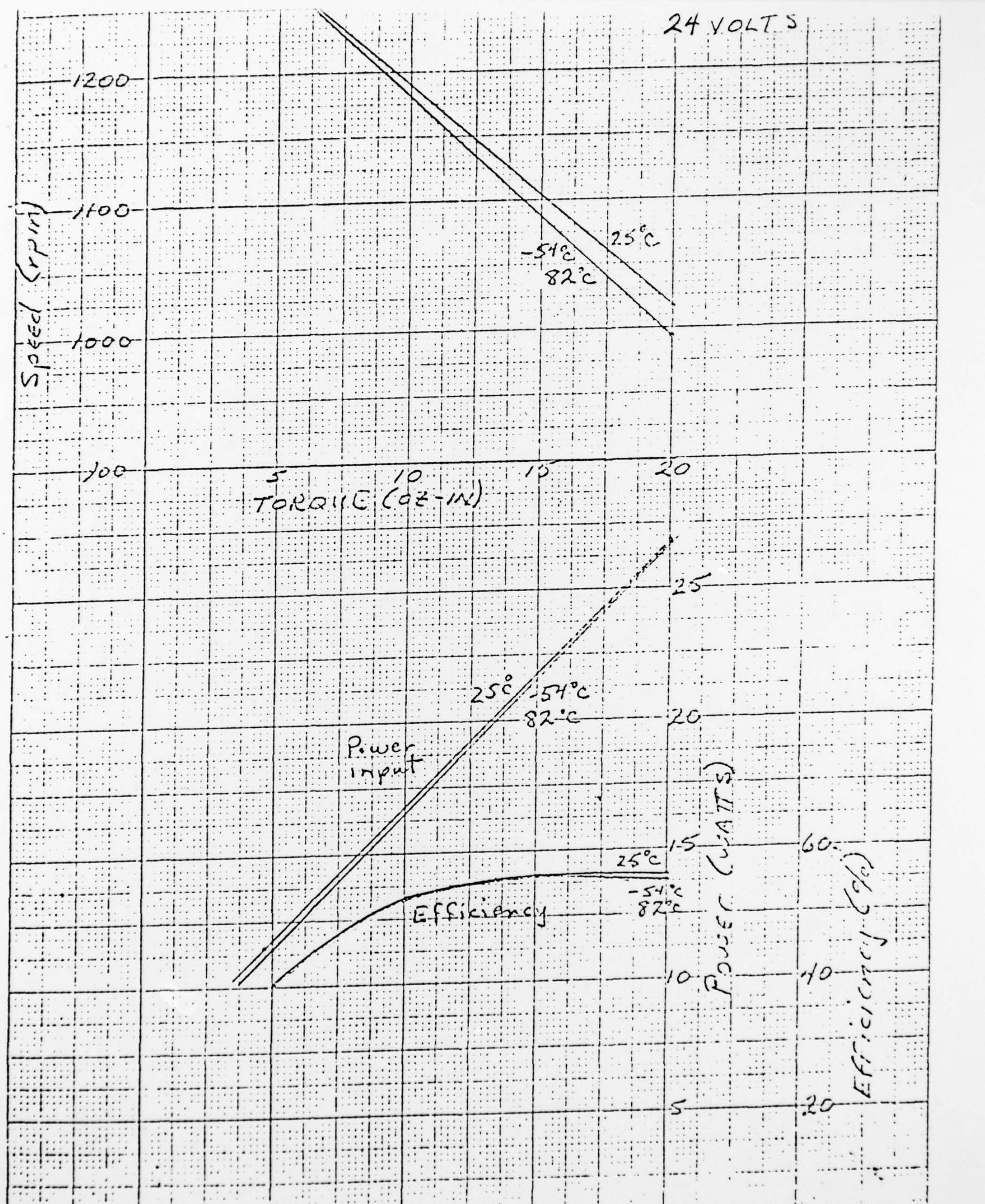
18 VOLTS
Speed (rpm)
1200
1100
1000
100
25°C
-54°C
82°C
5
10
15
20
TORQUE (OZ-IN)
25
25°
-54°C
82°C
20
Power input
15
10
5
25°C
-54°C
82°C
Efficiency
Power (WATTS)
60
40
20
Efficiency (%)

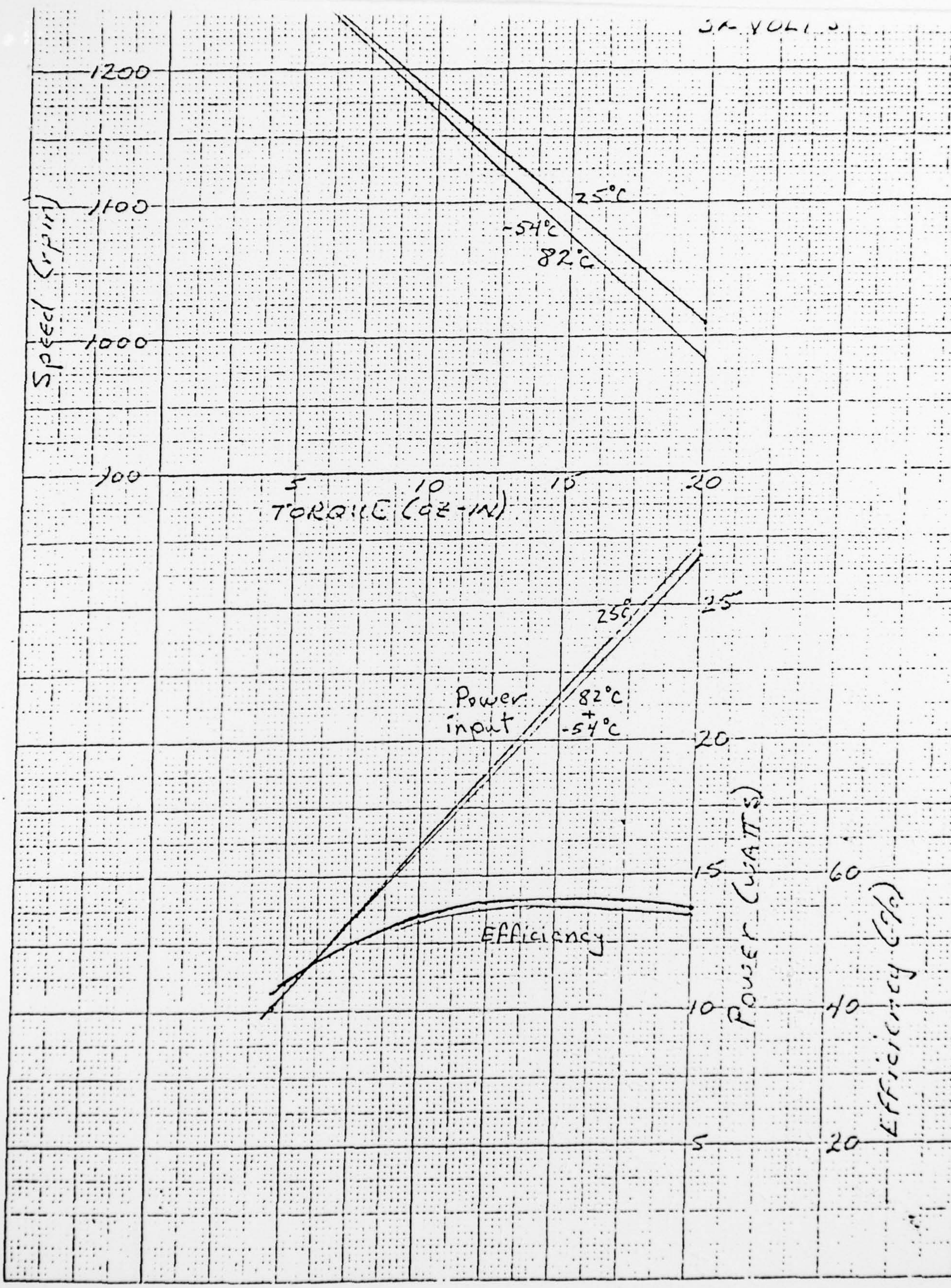

24 VOLTS
1200
1100
1000
900
Speed (rpm)
5
10
15
20
TORQUE (OZ-IN)
25°C
-54°C
82°C
Power input
82°C
-54°C
Efficiency
25
20
15
10
5
60
40
20
Power (WATTS)
Efficiency (%)



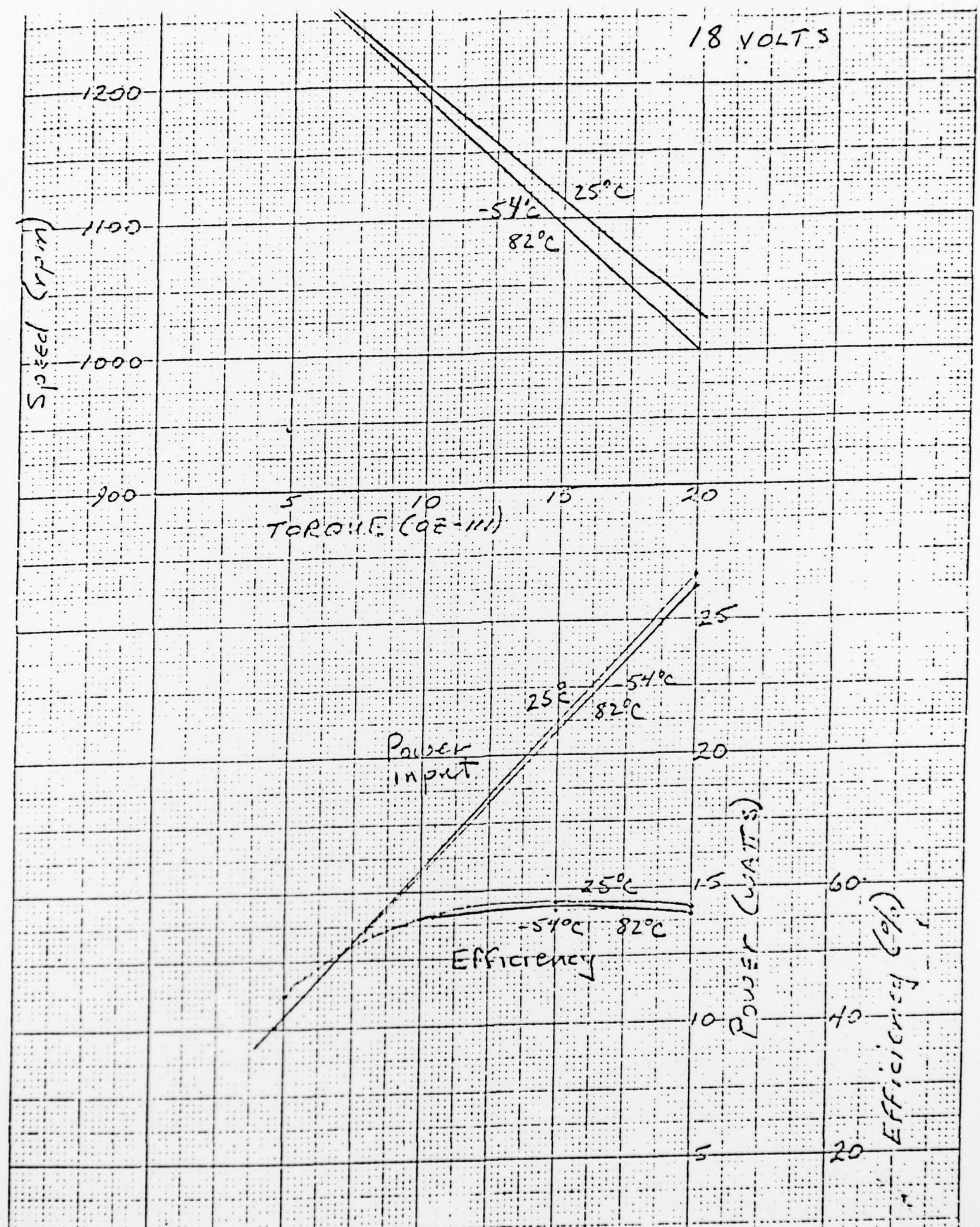
Speed (rpm)
1200
1100
1000
900
5
10
15
20
TORQUE (OZ-IN)
25°C
-54°C
82°C
Power input
25°
82°C
-54°C
Efficiency
Power (WATTS)
Efficiency (%)
25
20
15
10
5
60
40
20


18 VOLTS
Speed (rpm)
1200
1100
1000
900
-54°C
25°C
82°C
5
10
15
20
TORQUE (OZ-IN)
Power input
25°C
-54°C
82°C
25
20
15
10
5
Efficiency
Power (WATTS)
60
40
20
Efficiency (%)

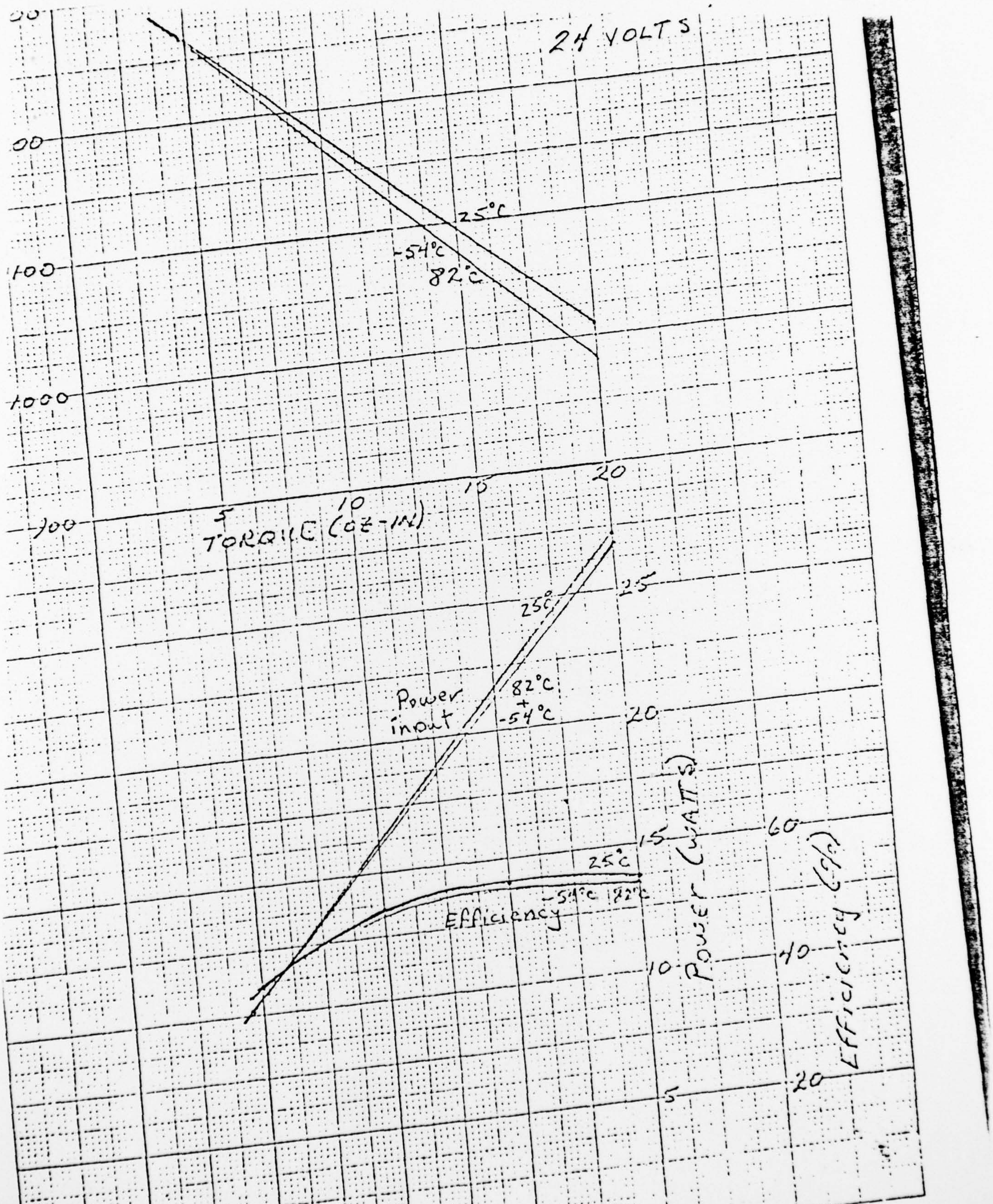

24 VOLTS
Speed (rpm)
1200
1100
1000
100
25°C
-54°C
82°C
5
10
15
20
TORQUE (OZ-IN)
25
25°C
-54°C
82°C
20
Power input
15
Power (WATTS)
60
25°C
-54°C
82°C
Efficiency
10
40
Efficiency (%)
5
20



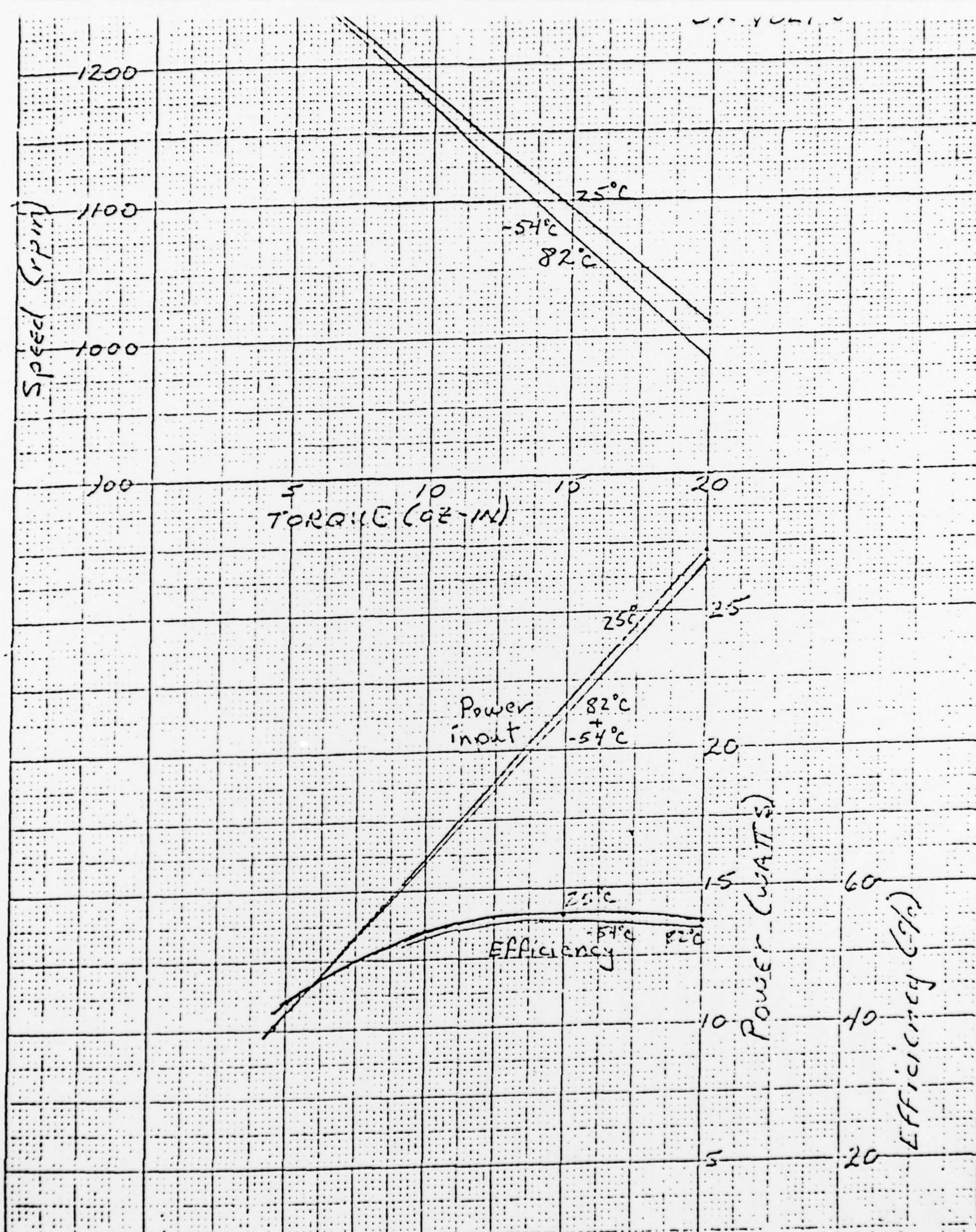
1200
1100
1000
900
Speed (rpm)
5
10
15
20
TORQUE (oz-IN)
25°C
-54°C
82°C
25°C
Power input
82°C
+
-54°C
Efficiency
25
20
15
10
5
Power (WATTS)
60
40
20
Efficiency (%)

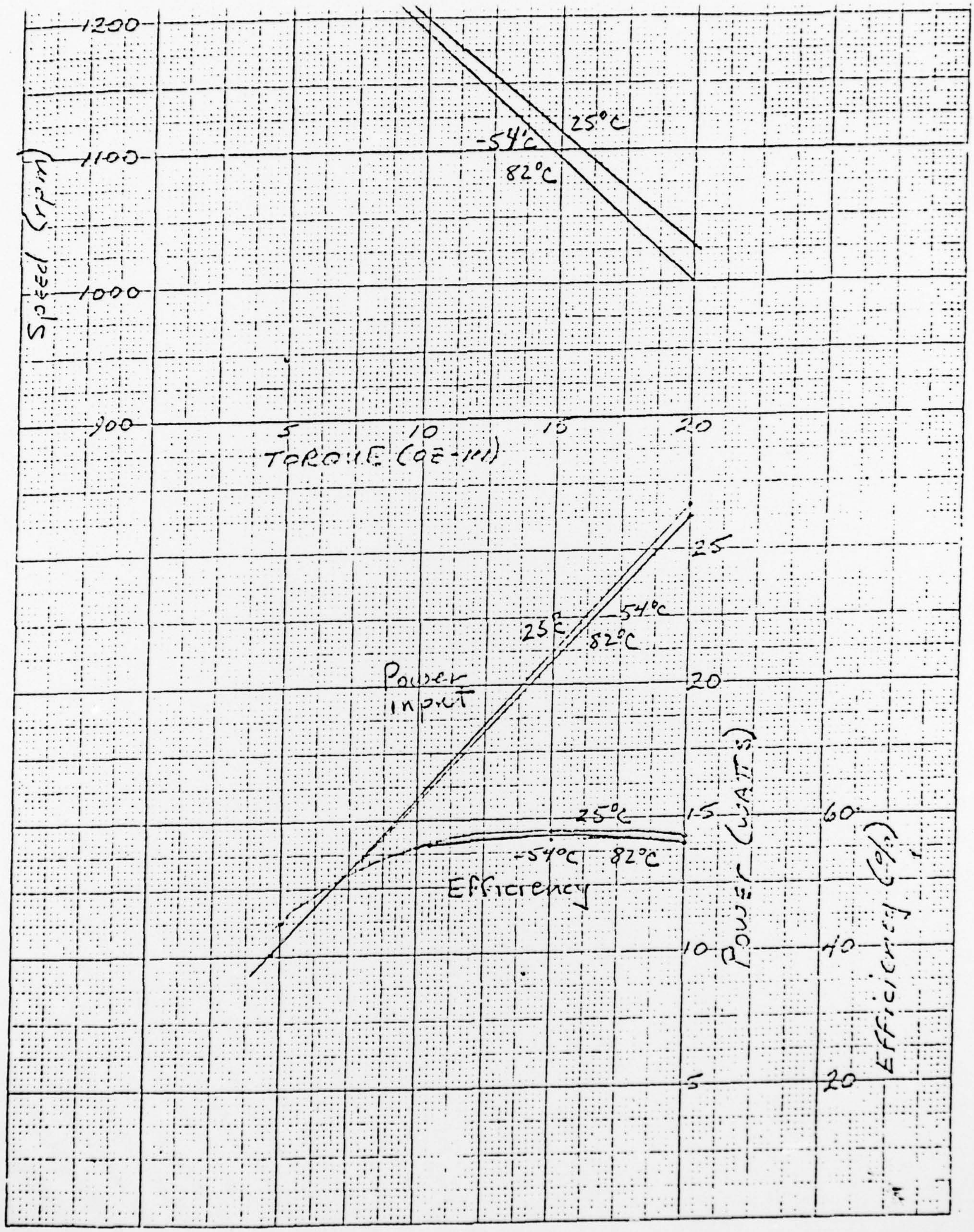


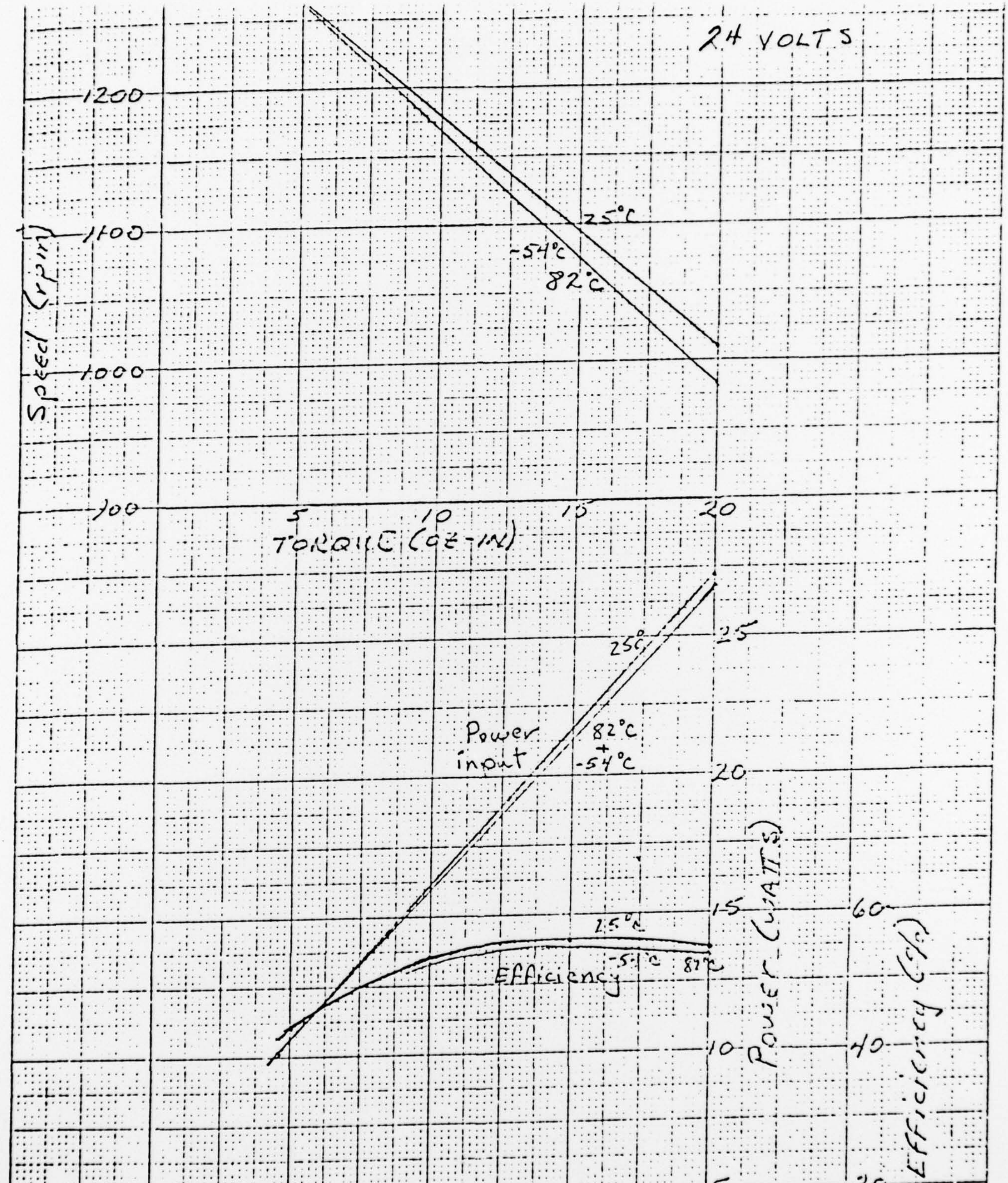
18 VOLTS
1200
1100
1000
900
Speed (rpm)
25°C
-54°C
82°C
5
10
15
20
TORQUE (OZ-IN)
25
20
15
10
5
-54°C
25°C
82°C
Power input
25°C
-54°C
82°C
Efficiency
Power (WATTS)
60
40
20
Efficiency (%)

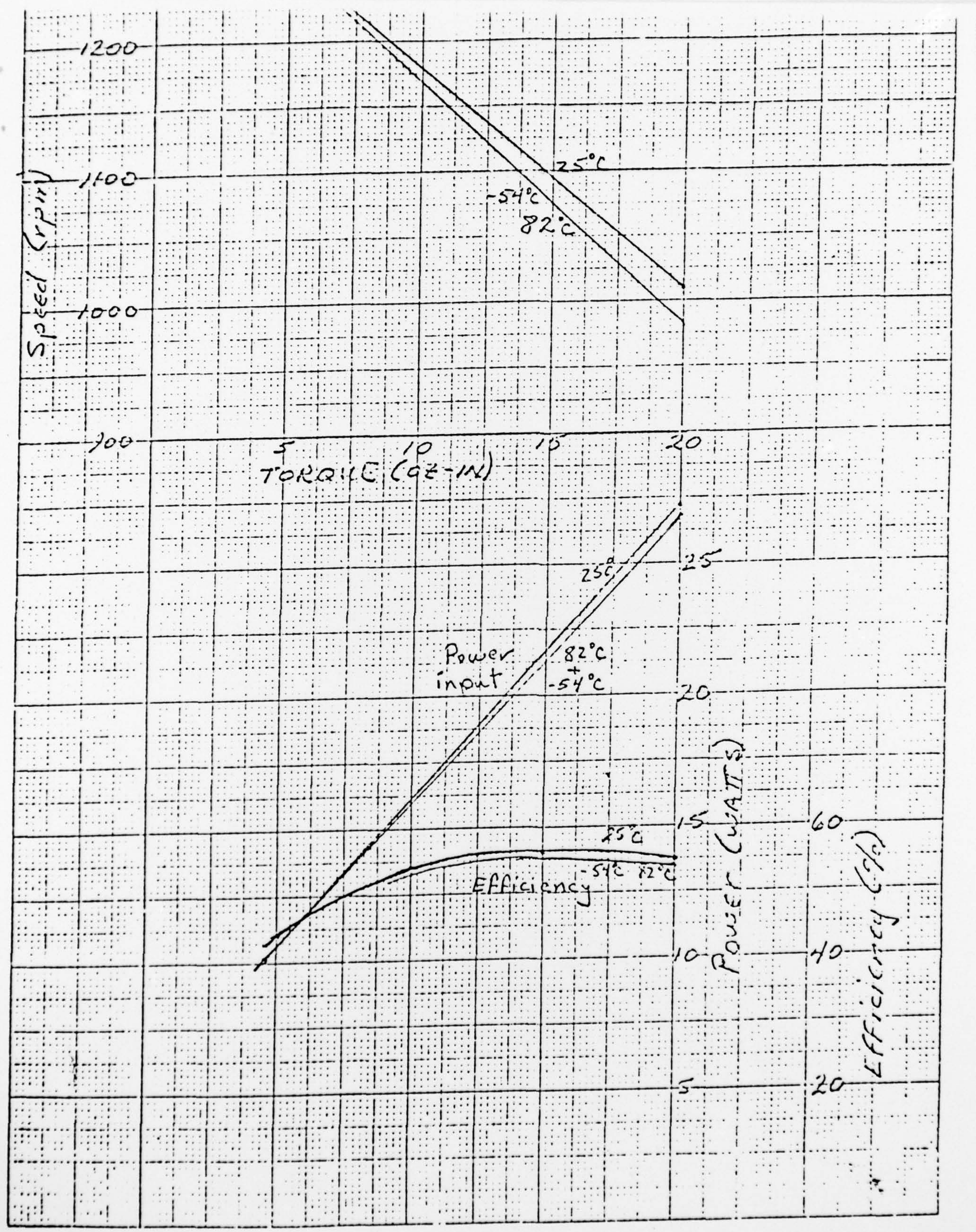


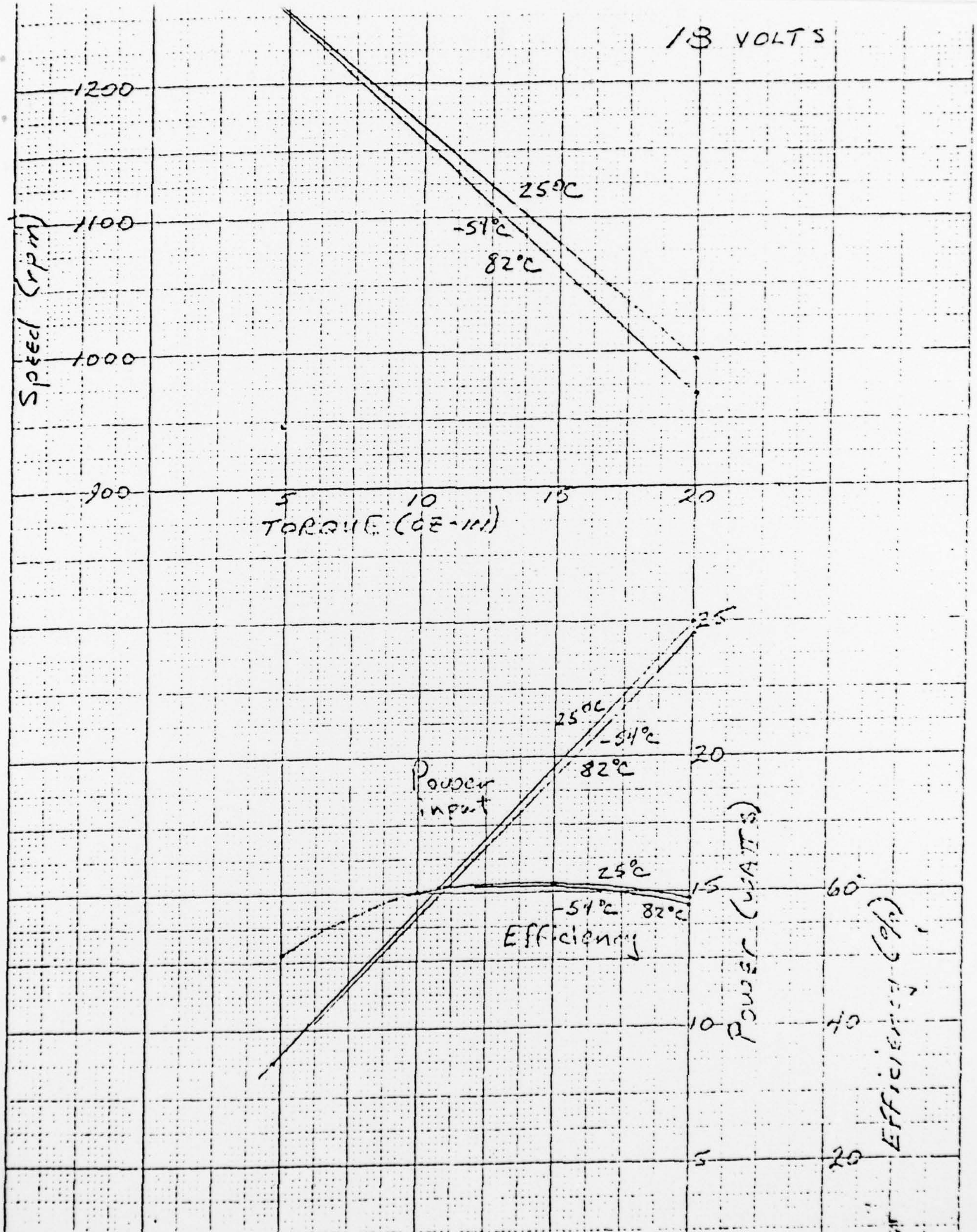
24 VOLTS
00
00
400
1000
-100
25°C
-54°C
82°C
5
10
15
20
TORQUE (OZ-IN)
25
25°C
Power input
82°C
+
-54°C
20
15
10
5
Power (WATTS)
60
40
20
Efficiency (%)
25°C
-54°C
82°C
Efficiency


1200
1100
1000
100
Speed (rpm)
25°C
-54°C
82°C
5
10
15
20
TORQUE (OZ-IN)
25
25°C
Power input
82°C
-54°C
20
15
10
5
60
40
20
25°C
-54°C
82°C
Efficiency
Power (WATTS)
Efficiency (%)

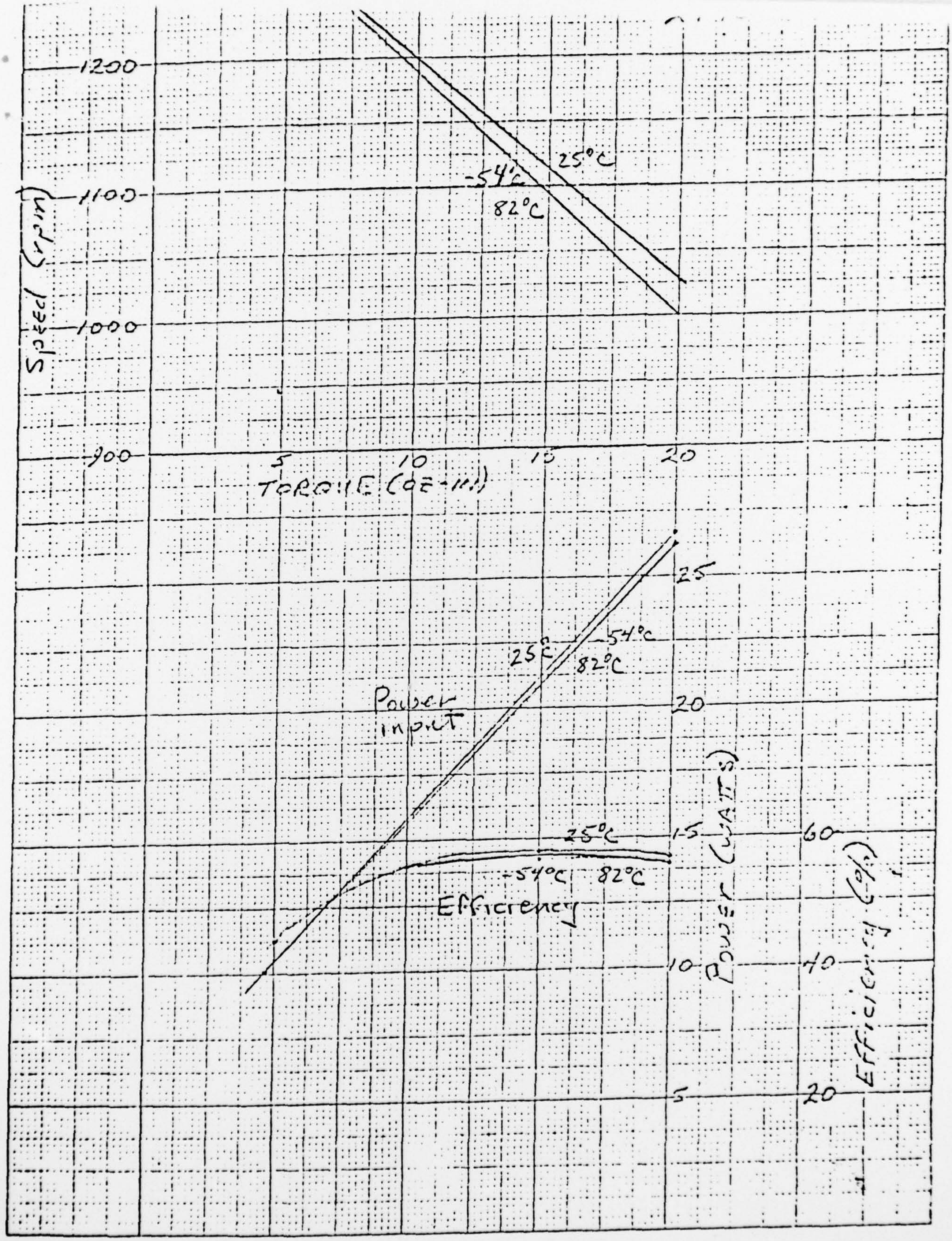

1200
1100
1000
900
Speed (rpm)
25°C
-54°C
82°C
5
10
15
20
TORQUE (OZ-IN)
25
20
15
10
5
60
40
20
-54°C
25°C
82°C
Power input
25°C
-54°C
82°C
Efficiency
Power (WATTS)
Efficiency (%)

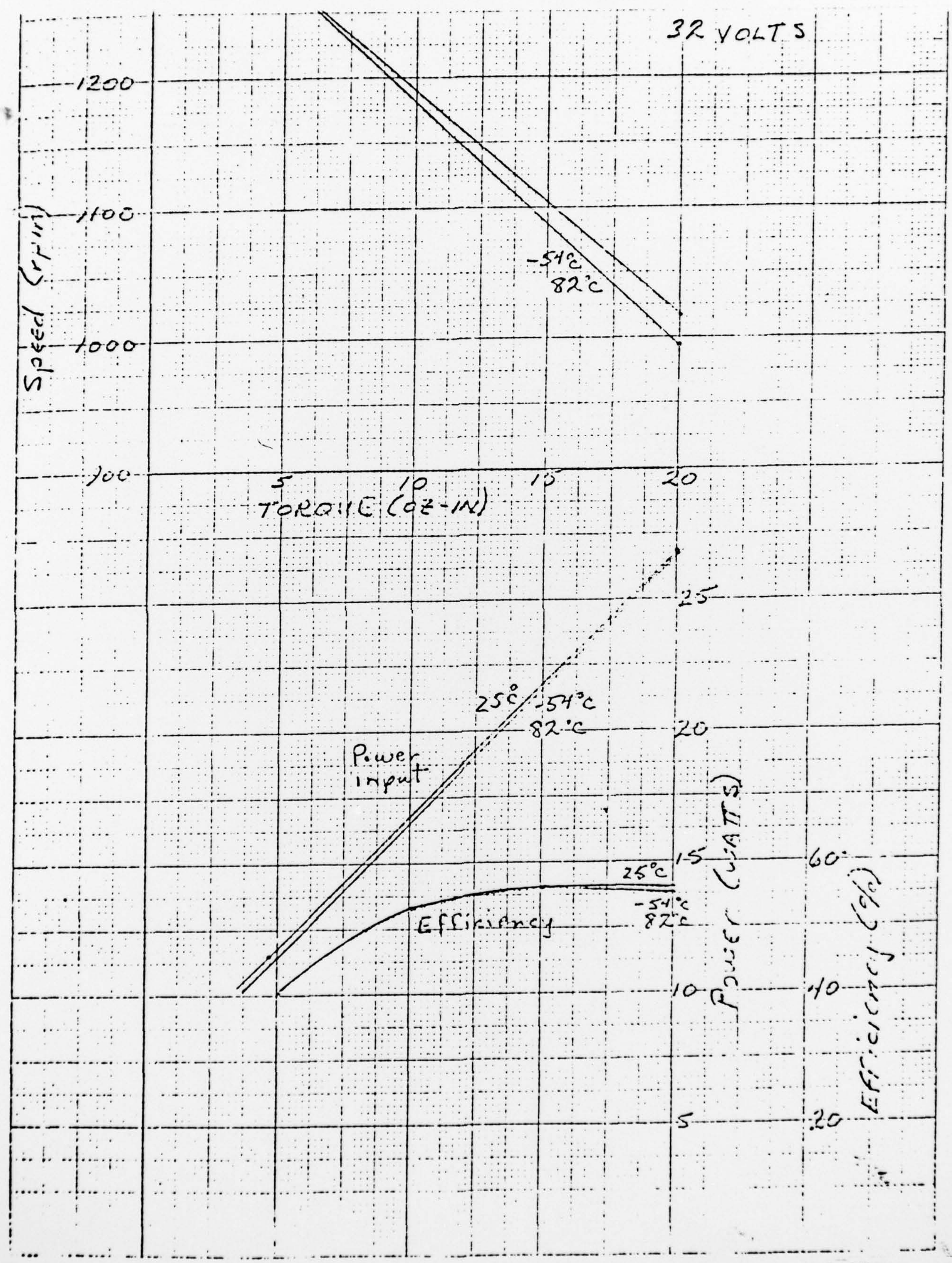

24 VOLTS
1200
1100
1000
900
Speed (rpm)
25°C
-54°C
82°C
5
10
15
20
TORQUE (OZ-IN)
25°C
Power input
82°C + -54°C
25°C
-54°C
82°C
Efficiency
25
20
15
10
5
Power (WATTS)
60
40
20
Efficiency (%)


1200
1100
1000
900
Speed (rpm)
25°C
-54°C
82°C
5
10
15
20
TORQUE (OZ-IN)
25
25°C
Power input
82°C
-54°C
20
15
10
5
Power (WATTS)
60
40
20
Efficiency (%)
Efficiency



18 VOLTS
Speed (rpm)
1200
1100
1000
900
5
10
15
20
TORQUE (OZ-IN)
25°C
-54°C
82°C
Power input
Efficiency
Power (WATTS)
25
20
15
10
5
Efficiency (%)
60
40
20


1200
1100
1000
900
Speed (rpm)
25°C
-54°C
82°C
5
10
15
20
TORQUE (OZ-IN)
25
20
15
10
5
25°C
-54°C
82°C
Power input
25°C
-54°C
82°C
Efficiency
60
40
20
POWER (WATTS)
Efficiency (%)


32 VOLTS
1200
1100
1000
900
Speed (rpm)
-54°C
82°C
5
10
15
20
TORQUE (OZ-IN)
25
20
15
10
5
25°C
-54°C
82°C
Power input
25°C
-54°C
82°C
Efficiency
Power (WATTS)
60
40
20
Efficiency (%)